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THE
JOURNAL OF GEOLOGY

A Semi-Quarterly Magazine of Geology and Related Sciences

VOLUME VIII

CHICAGO
The University of Chicago Press
1900

PRINTED BY
The University of Chicago Press
CHICAGO

Contents of Volume VIII.

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THE

JOURNAL OF GEOLOGY

JANUARY—FEBRUARY 1900

SUGGESTIONS REGARDING THE CLASSIFICATION OF THE IGNEOUS ROCKS

It may well be doubted if there is any science which presents greater difficulties to the teacher than that of systematic petrology—the classification of rocks. Even the name itself is seldom used, and appeals to the petrologist as almost a misnomer, because the science is so lacking in system, or, shall we say, overburdened by "systems." The German petrologists, under the leadership of Rosenbusch and Zirkel, and the French with Michel-Lévy at their head, are committed to the partial use of "systems" which are regarded as obsolete by their colleagues in other lands. The English and American schools of petrology have each their "systems" which differ from the German "systems" and more or less from each other. Yet as all are using essentially the same language of terms, the confusion which has arisen is so great that it is now necessary in employing a rock name to state at length what meaning the word is intended to convey.

Such a state of affairs is explainable on two grounds: first, the hesitancy felt in departing from the views held by the fathers of the science, and, second, the inherent difficulties which lie in the science itself, due to the complex nature of rocks.

The modern petrographical microscope, with its accessories, has introduced great refinement into the methods of study, so that descriptive petrology, or petrography, has become a very exact science. It is now possible to describe a rock in so many ways (in respect to so many of its attributes, such as mode of occurrence, texture, mineral composition, chemical composition, alterations, genesis, etc.,) that the difficulties in the way of bringing the results of the study into an orderly classification have been greatly increased. Nor is there reason to hope for any immediate remedy for this condition, since the largest and most representative body of petrologists ever assembled — the Seventh International Congress of Geologists, at St. Petersburg — was almost unanimous in the conviction that it would be useless to attempt to harmonize the nomenclature of the science by any early action of that body. The view was, however, expressed that something might be accomplished through the labors of a representative committee, which should, by frequent and careful deliberations, arrive at a tentative scheme for presentation to a future congress.

Undoubtedly the greatest obstacle in the way of reaching an understanding in the matter is that different values are assigned by different petrologists to the same attribute in rock classification. Some would lay greatest stress upon the mode of occurrence in the field; others would give the first place to mineral constitution, still others to texture, chemical composition, etc.

THE FIELD GEOLOGIST VS. THE PETROLOGIST

In deciding what shall be given first place as a basis in any system of rock classification, it should be realized, it seems to me, that the igneous rocks are not the sole property of the petrographer. The field geologist or the "naturalist," whatever be his special line of work, has need to make determination of igneous rocks, and he has a right to ask of the petrographer, who from his greater familiarity with rocks is charged with arranging them in an orderly system, such a classification that the geologist's determination in the field shall be *incomplete* rather

than *incorrect.* It should be made possible for the geologist to determine correctly at least the family to which a rock belongs, leaving to the petrographer the determination of rock species as well as the solution of the purely petrological problems.

To aid his eye the field geologist has only his pocket lens, and whatever rock species are fixed upon by petrologists they should be grouped into a comparatively small number of families, limited by simple and easily tested characteristics. In the case of the volcanic rocks it would be necessary to adopt terms broad enough to cover all rock types which it is found impossible to easily distinguish in the field. This reform would be made in the interest of the petrographer quite as much as of the geologist. If this be done the petrologist may multiply terms as he will to express any extension of his refined methods of study without in any way disturbing the composure or the effective work of the great body of field geologists.

BEARING OF RECENT PETROGRAPHICAL STUDIES ON ROCK CLASSIFICATION

From the point of view of the systematic petrologist the two most significant developments of petrology during the closing years of the nineteenth century have been, first, the numerous observations showing that the time honored families of igneous rocks, once supposed to be more or less sharply delimited, pass by insensible gradations into one another; and second, the return of chemical composition as a basis of rock classification to a position of prominence nearer to that which it formerly occupied.

The attention of petrologists was first drawn to the marked facial differentiation of a rock magma when the late Professor George H. Williams showed that rocks as diverse as quartz-mica-diorite and peridotite occur in the same stock near Peekskill, N. Y.[1] Since that time other investigators, but notably Iddings, Brögger, Ramsay, and Weed and Pirsson, have multiplied the

[1] G. H. WILLIAMS, The Gabbros and Diorites of the "Cortlandt Series," on the Hudson River near Peekskill, N. Y. Am. Jour. Sci. (3) XXXV, pp. 438–448, 1888.

observations of other but similar cases of magmatic differentiation. It is now the exception rather than the rule to discover an igneous rock mass of considerable dimensions in which some evidence of such gradations may not be observed.

The introduction of the petrographical microscope and its accessories, bringing as it did quick and delicate methods for determining the mineral constitution of a rock, naturally enough drew away the attention of petrographers from the slower and less brilliant methods of chemical analysis, which up to that time had been almost the only ones in use. Moreover most of the analyses of the period were, as we now know, inaccurate and failed to show the real chemical differences between individual rocks. The multiplication of the number of analyses and the improvements in the methods of rock analysis which have been made during the last decade, particularly by Hillebrand, have disclosed important differences among rocks formerly classed together, and thus necessitated a considerable elaboration of the systems of classification.

With this elaboration rock names have been introduced into the science with a rapidity which is little short of bewildering. The older petrological nomenclature was largely binomial or polynomial (*i. e.*, mica-syenite, quartz-mica-diorite) though the recent names seem planned for a monomial nomenclature (*i. e.*, ciminite). It is therefore not strange that misunderstanding has arisen in some quarters, where it is not realized that the new names proposed are for the most part specific and varietal in their nature and in no way to be correlated with the great family names such as granite or gabbro, and hence a protest has been made against what seems a needless overburdening of the science with names. Without entering upon this question here it may, I think, be stated with all assurance that some reforms are imperatively demanded before the worker will be fully equipped to discover the relationships among rocks because of the incubus of unclassified facts by which the science is now encumbered. Some of the particular reforms which to me seem desirable and practicable will be briefly described.

The definition of a rock as an object rather than as an integral part of the earth's crust.—The Wernerian conception of a rock as a geological unit or integral part of the earth's crust, still held by German petrologists, was adequate enough so long as rock masses were regarded as essentially homogeneous. With the discovery that such masses are usually quite heterogeneous and frequently represent not only several rock species but sometimes include almost the whole gamut of rock families, it became necessary to adopt some other definition. No other course seems open under these circumstances than to consider the individual rock specimen as the unit of classification and describe it primarily as an object, as is done with the units in the systems of other sciences.[1] If this is done it should be possible to *name* a rock from study of the specimen only though the *full description* would involve no less of field study than is undertaken when rocks are classified on the basis of their geological occurrence.

The importance of texture as a basis of classification.—All systems of classification of the igneous rocks emphasize more or less strongly rock texture as a basis of classification, for the reason that the texture is one of the properties of a rock most easily examined; and, further, because it is dependent so largely upon the peculiar conditions of rock consolidation or subsequent metamorphism. If rocks are described as objects this property of texture becomes inevitably of the very first importance.

The two main groups of the igneous rocks which are now generally recognized as distinguishable on the basis of texture are: first, those having a texture designated by Rosenbusch as *hypidiomorphic granular*, but which may in simpler language be referred to as *granitic*, the essential characteristic of which is that the mineral constituents by their manner of interlocking indicate for the rock in which they occur practically an uninterrupted period of crystallization; and, second, the *porphyritic*

[1] Cf. WHITMAN CROSS, The Geological *vs.* the Petrological Classification of Igneous Rocks. JOURN. GEOL. VI, p. 79, 1898. See also TEALL, British Petrography, p. 65.

texture in which the occurrence of two or more generations of the same constituent mineral indicates that the process of consolidation was not a continuous one but consisted of two or more stages.

The time honored but now obsolescent classification of igneous rocks on the basis of geological age has left us as a legacy a double nomenclature for the rocks of porphyritic texture, and this may be well illustrated by the terms "quartz porphyry" and "rhyolite" applied to rocks of porphyritic texture having a chemical composition similar to the granites. The former in its traditional, and also in its present German signification, refers to rocks of pre-Tertiary age, the latter to Tertiary or later rocks. The tendency of American petrographers seems to be to abandon entirely terms of the class of "quartz porphyry" and to extend the terms correlated with "rhyolite" to cover the rocks which were previously included in both groups. This tendency seems to me to be an unfortunate one since it results in classing together rocks which are essentially unlike. There may be no important difference between a particular "quartz porphyry" and a particular "rhyolite," but compare a drawer of hand specimens of the former with one of the latter and argument is unnecessary to show that as classes they are essentially different. The "quartz porphyries" are, as a class, devoid of vesicular and fluxion structures—they are in their mode of occurrence hypabyssal—and they more generally show the effects of devitrification, weathering, etc.

The "rhyolite" class of rocks may be conveniently distinguished from the "quartz porphyry" class by the possession of either vesicular or rhyolitic (fluxion) textures. Correspondence with some representative American petrographers has indicated to me that a restriction of the terms, rhyolite, trachyte, andesite, basalt, etc., to describe porphyritic types possessed of rhyolite or vesicular textures, would meet with considerable favor. Though of these terms rhyolite alone in its derivation calls attention to a fluxion texture, the others by their usage (trachytic structure, andesitic structure, etc.) have been given

the same significance. The terms, rhyolite-porphyry, trachyte-porphyry, andesite-porphyry, etc., by their substitution for the objectionable names, quartz-porphyry, quartzless porphyry, etc., would carry with them the idea of varietal rather than specific variation from the family type, and would, moreover, obviate the danger of their being interpreted in terms of the age classification.

Combination of chemical and mineralogical composition as a basis for rock classification.—Probably the majority of those petrologists who define rocks as objects would agree that chemical and mineralogical composition with texture should occupy the foremost places in rock classification.[1] It would probably be more satisfactory, were it practicable, to adopt chemical composition divorced from mineral composition as the primary basis in classification, but we are, per force, compelled to look first to the mineral composition, and work backward from this to the chemical composition—the chief factor in determining mineral composition. In the past the mineralogical examination of rocks has been largely qualitative, resulting, in some cases, in the classing together of rocks strikingly different as regards their ultimate chemical composition, but a stage has now been reached where such a method is no longer adequate. Pirsson has called attention to the necessity of paying greater regard to the relative quantities of the several essential constituents of a rock, thus making a rough estimation of its ultimate chemical composition.[2]

Specific, generic, and family rock names are applied to arbitrary rock types separated from one another by no sharp lines.—It follows, from the gradations generally observed to connect the families of the igneous rocks, that the names which we adopt to designate any individual rock, or class of rocks, is applied as a *type* name in the sense that it applies to a particular rock or collection of related

[1] Cf. TEALL: British Petrography, p. 69; WHITMAN CROSS: loc. cit., p. 80; J. P. IDDINGS: On Rock Classification, JOUR. GEOL., 1898, VI, p. 93; F. ZIRKEL: Lehrbuch der Petrographie, I, p. 829, 1893; W. C. BRÖGGER: Die Gesteine der Grorudit-Tinguait Serie, Christiania, 1894, p. 92.

[2] Igneous Rocks of Yogo Peak, Montana, Am. Jour Sci. (3) L, p. 478.

rocks, descriptions of which have been placed on record. The lines separating the several types are fixed arbitrarily, and would, in general, be located somewhat differently if undertaken at the outset by different individuals. For the types of larger order, these lines have been fixed by the traditional rock groups, and they are not likely to be much changed, but for the new and specific types they will be largely determined by the particular rock areas which are first examined.

A much more general use of intermediate family type names is inevitable, and terms like grano-diorite (or better, granito-diorite), trachy-andesite, etc., should be utilized.[1]

Rock relationships should be indicated by the combination of names into a binominal, or, if necessary, polynominal nomenclature.—The multiplication of specific terms, whose derivation has only a geographical signification (*e. g.*, Toscanite, Absarokite, Litchfieldite), furnishing not the slightest indication of the rock's relationships, is fast bringing petrologists to the condition of the Chinaman who is required to learn a unique syllable for every word in his language. Not possessing the admirable memory training of the Chinaman, the petrographer finds himself somewhat bewildered under the rain of new petrographical names which has characterized the closing years of the century. Many of these terms have been rendered necessary by the elaboration of the system of classification, due to the improved methods of chemical examination, and to the discovery of new petrographical provinces, and others are sure to be needed, but the enterprise in this branch of the science manifested in some quarters has sometimes provided us with two, or even three, names for the same specific rock type.

There can be no question that the nomenclature of petrography can be greatly simplified by a return to a binomial or polynomial nomenclature, which, fortunately, can be accomplished without much confusion, provided the old names of rock families be retained, together with compound names for the gradational types connecting them. An illustration may be

[1] Cf. Brögger: op. cit., p. 93.

furnished by the interesting types, Toscanite, Vulsinite, and Ciminite, recently described by Washington.[1] They form together an intermediate family connecting the trachytes with the andesites, and called by Washington, trachy-dolerite, though it seems to me trachy-andesite is to be preferred. Trachy-dolerite-ciminite, or trachy-andesite-ciminite, is a term which tells at once that the rock to which it applies is a species of trachy-andesite which has been described from Monte Cimino. The term latite proposed by Ransome[2] for this group, while otherwise appropriate, fails to show the family relationships. Van Hise[3] has already suggested such a compounding of terms to express relationships. Certainly if the nomenclature of the science is to aid rather than to distract the worker some such reform from present conditions is demanded.

Graphical methods essential to a comprehensive study of rock analyses.—The necessity for studying the chemical composition in connection with the mineral composition of a rock requires that we examine in connection with one another the chemical analyses of all rocks having the same mineral constituents; or, better, those having the same constituents in the same relative quantities to a rough approximation. Such analyses show variations of one, two, or more per cent. in the quantities of some of the constituents for a single species or variety. But, on the other hand, differences of one or two per cent. in the amount of a constituent may be the cause of important differences in mineral composition or in other characteristics of the rock; hence it is important to know to that degree of precision the amount of each constituent which is present. For each analysis that would be remembered, it is necessary, then, to keep in the mind eight numbers of one or two figures each; and the student of petrology who would be familiar with the chemical nature of any

[1] H. S. Washington: Italian Petrological Sketches, No. 5, Jour. Geol., V, pp. 349–377, 1897.

[2] F. Leslie Ransome: Some Lava Flows of the Western Slope of the Sierra Nevada, Cal., Am. Jour. Sci. (4), V, p. 373, 1898.

[3] C. R. Van Hise: The Naming of Rocks, Jour. Geol., VII, pp, 691–693, 1899.

given rock type must know the range in the percentages of the eight principal constituents. Moreover, he is not assisted in this by the knowledge that the upper and lower limits which he learns for a constituent of one species are at the same time, respectively, the lower and the upper limits for the same constituent in other allied species. A tax is thus imposed upon the memory far beyond what it may be reasonably expected to bear, and this tax is increased with the fixing of each new rock species.

The eye assists the mind not only to discover intricate relationships, but also to retain them, whenever the facts can be expressed by a definite form. This has been appreciated especially by the engineering profession, which has been accustomed, by the use of diagrams, to set forth in the most lucid manner facts which only the most laborious methods could otherwise bring out of the tables on which they are based. A curve contains the essence of pages of figures, and is readily carried in the mind owing to the large development of that faculty, which the Germans have so aptly termed *Vorschauungsgabe*. It is noteworthy that so little attempt has been made to apply graphic methods in petrology.

Recently, however, Iddings,[1] Becke,[2] Michel-Lévy[3] and Brögger[4] have each devised diagrams to illustrate rock analyses.

Of these the diagrams of Brögger seem to me the ones best adapted for general use because the simplest and the most characteristic. In the Brögger[5] diagram are set off on radius vectors the amounts of the eight principal chemical constituents reckoned

[1] J. P. IDDINGS: The Origin of the Igneous Rocks, Phil. Soc. of Washington. XII, pp. 89–214. Pl. II, 1892; Absarokite-shoshonite-banakite series. JOUR. GEOL., III, pp. 90–97, 1895; On Rock Classification, *ibid.*, VI, p. 92, 1898; Chemical and Mineralogical Relationships in Igneous Rocks, *ibid.*, p. 219.

[2] F. BECKE: Die Gesteine der Columbretes. TSCHERMAK'S min. u. petrog. Mittheil., VI, p. 315. 1897.

[3] M. MICHEL-LÉVY: Porphyr bleu de l'esterel, Bull. de la sèrvice de la carte géol. de la France. Tome IX, No. 57, 1897; Sur une nouveau mode de co-ordination des diagrammes representant les magmas des roches éruptifes. Bull. de la soc. géol. de la France. (3) XXVI, p. 311.

[4] W. C. BRÖGGER: Die Eruptivgesteine des Kristianiagebietes; Das Ganggefolge des Laurdalits. Kristiania, 1898, p. 255. Pl. I.

[5] Or LÉVY-BRÖGGER diagram.

in molecular ratios, ferrous and ferric iron being entered upon the same radius vector, and silica, because so much in excess of the others, being evenly divided between the two horizontal radius vectors. A broken line joining the intercepts on the eight radius vectors forms a polygon, which may be long and narrow, or short and thick, convex above or below, or reëntrant in any portion, left or right handed, etc., according to the chemical constitution of the rock.

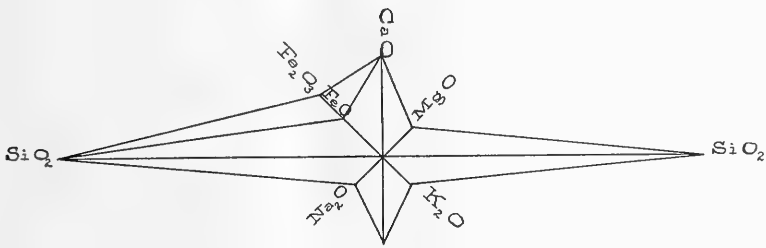


FIG. 1.

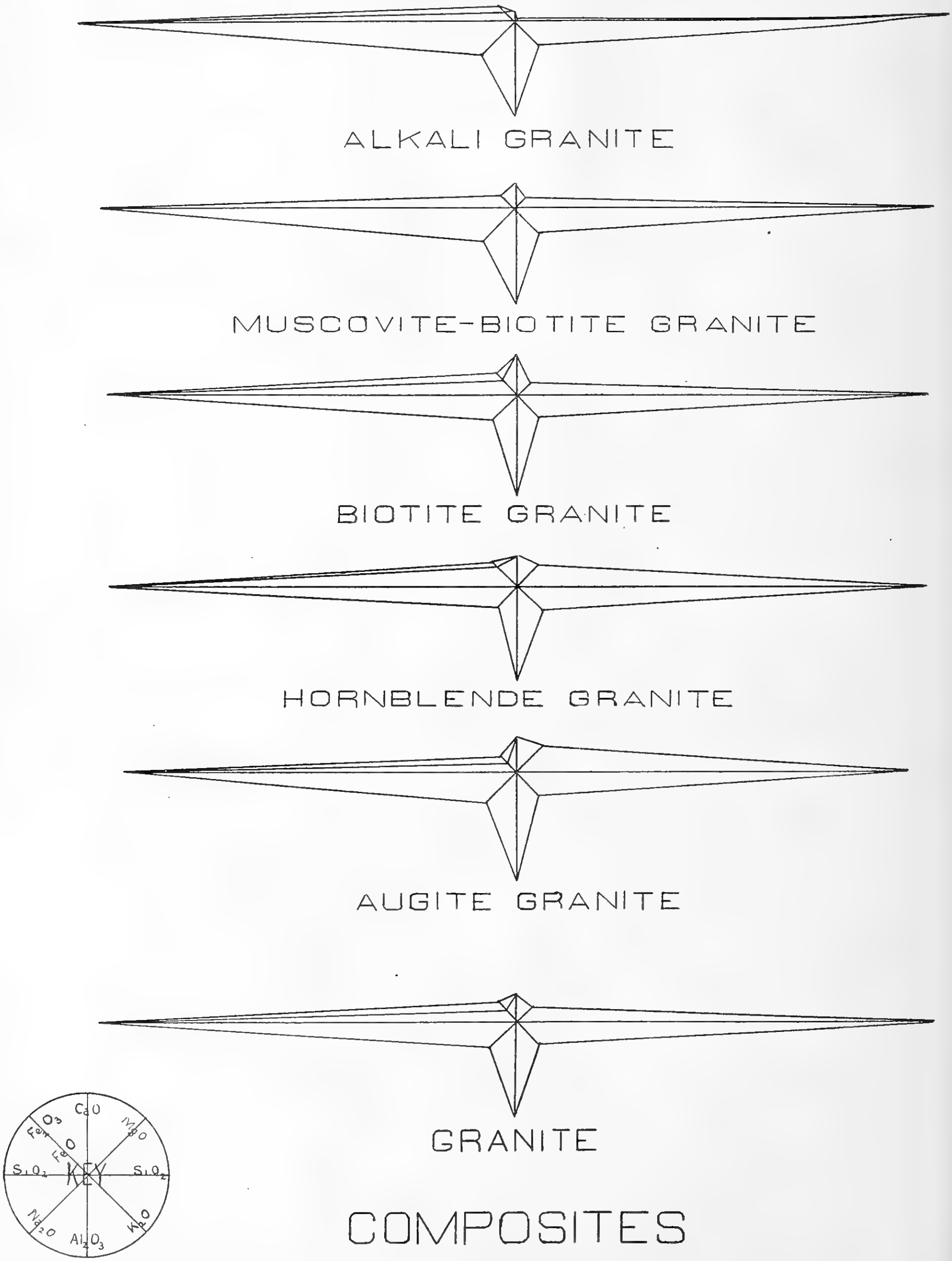
When viewed in this diagram, the rock comes to have a handwriting by which it may be instantly recognized. When drawn to scale, this diagram not only shows the chemical character of the rock but all the results of analysis may be quickly read from it numerically.[1] In it, as in all other successful diagrams the molecular ratio is substituted for the percentage of each constituent. Some authors now publish these ratios with every rock analysis. It is to be hoped that this will soon become a general custom.

THE COMPOSITE ROCK DIAGRAM

The principal objection to Brögger's diagram is that it represents not a rock species or a rock type but only an individual analysis, the rock type covering a considerable range of differing analyses. So far as I know, only isolated attempts have been made to average rock analyses to secure an adequate conception of the chemical constitution of the rock type, although the method of averaging results is so successfully used in other fields of science.

[1] On plates I, IV, V, and VI, .01 equals 1^{mm}.

Jour. Geol., Vol. VIII, No. 1 Plate I

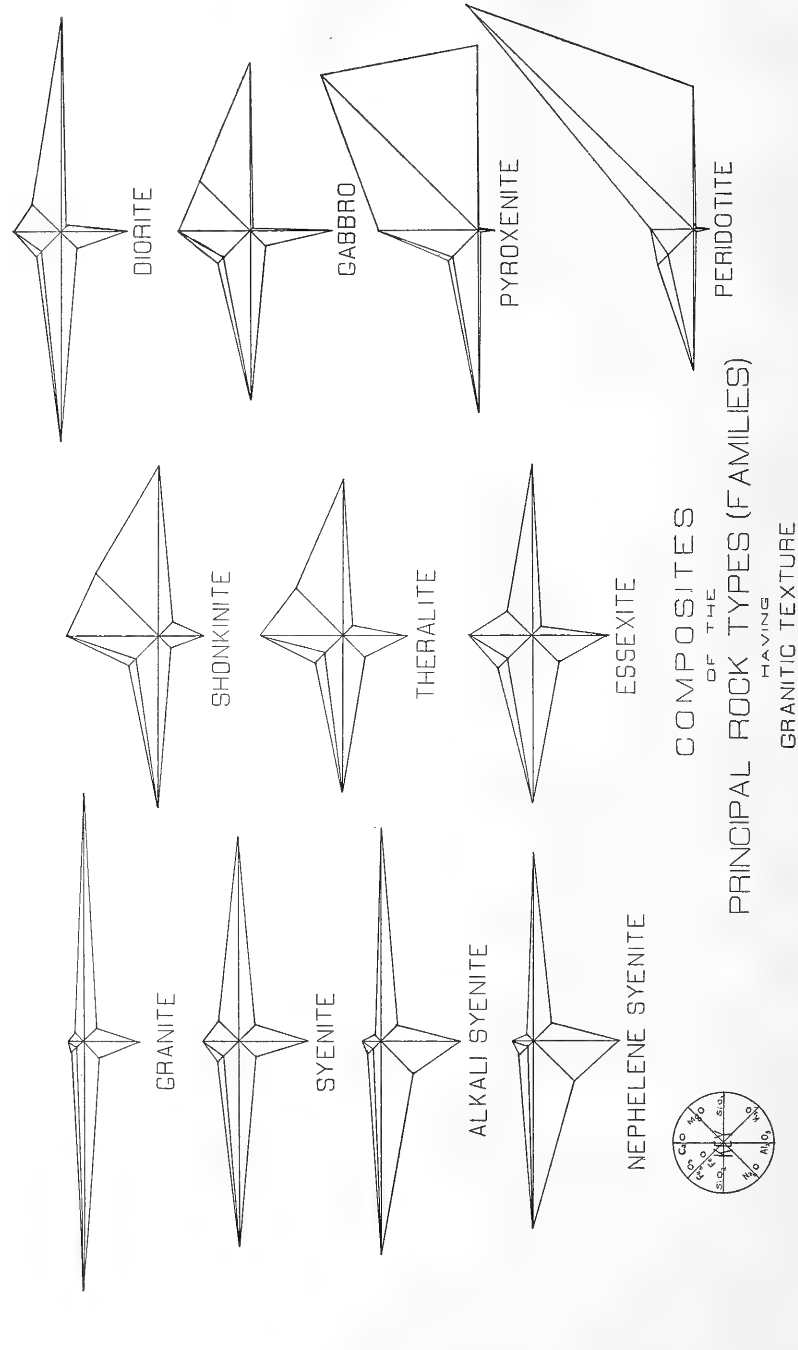


COMPOSITES

In connection with his class in petrology, the writer has for some time made use of diagrams which set forth the average composition of rock types. There are two ways in which such diagrams may be constructed. On the one hand, the diagram may be prepared after the same manner as composite photographs. The Brögger diagrams of a considerable number of representative rocks faintly outlined are superimposed upon the same radius vectors, so as to indicate the range in ratios of each constituent and in the darkest part of the figure the characteristics of the type. A composite diagram, better adapted for general use, because so much less intricate and so much easier to prepare, is obtained by first averaging the molecular ratios of each constituent for the group of analyses, and using the results to prepare a single diagram, which then becomes the diagram of a type instead of that of an individual.

The writer has so far modified the Brögger diagram as to draw the radius vectors so as to make equal angles with one another. The closed polygon obtained by connecting the intercepts on the different radius vectors has a form which changes in a marked degree to correspond with the changes in the length of any radius vector. Since the soda, potash, and alumina are all measured below the horizontal, acid rocks show diagrams stretched out along the horizontal and developed also below the horizontal; while the protoxide bases being all entered above the horizontal basic rocks are short and "fat above." Soda-rich or potash-rich rocks give respectively left-handed and right-handed diagrams, etc. All these facts the eye soon accustoms itself to take in at a glance and subconsciously, as it does in the case of handwriting. It is hardly necessary for the eye to estimate the lengths of the intercepts (a feat it is but poorly qualified to accomplish) for the ratios of the quantities of the constituents to one another is shown by the *angles of slope* of the polygonal sides — something which the eyes easily measures. The larger the number of correct and properly selected analyses which are utilized in obtaining the "composite" of any type, the greater is its value.

JOUR. GEOL., VOL. VIII, NO. 1 Plate II



STUDY OF THE COMPOSITES OF THE PRINCIPAL FAMILY TYPES OF THE IGNEOUS ROCKS HAVING GRANITIC TEXTURE

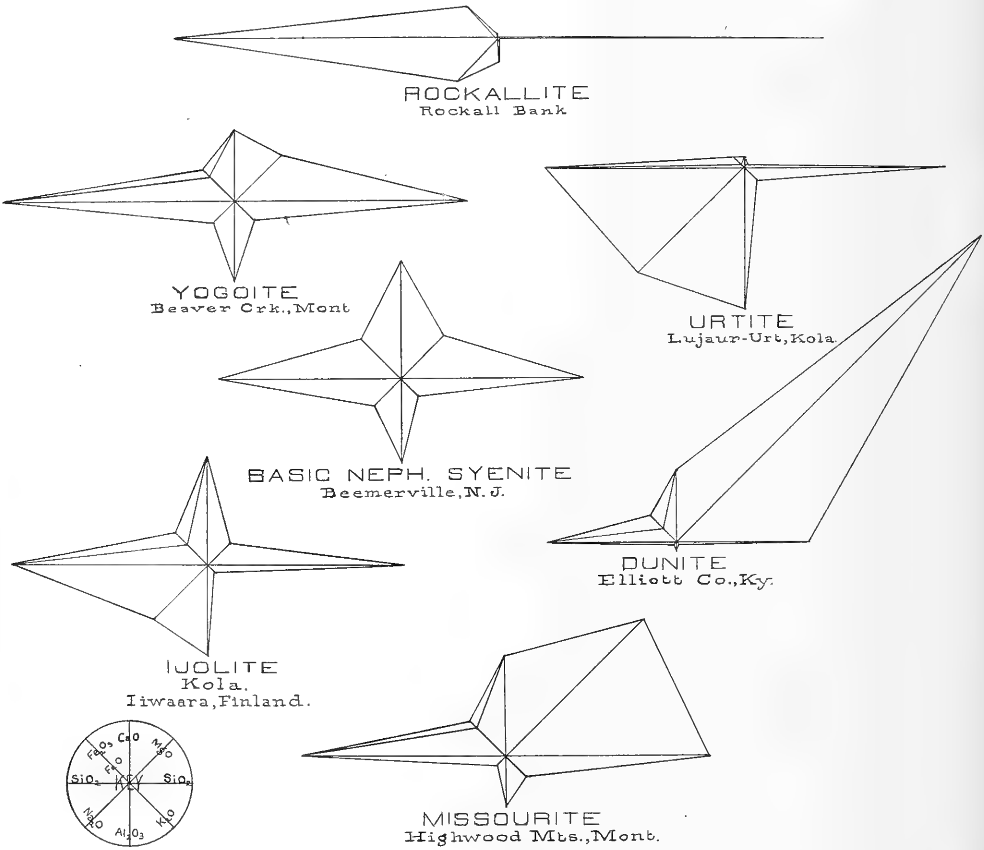
The composite diagram may be made to represent either specific or family types according to the analyses which are combined to produce it. By combining separately analyses of the principal species of granite, viz., alkali-granite, muscovite-biotite-granite, biotite-granite, hornblende-granite, and augite-granite, we are prepared to draw the composite diagram of each and can then compare them with one another; or, if we choose, we may compose all to form a single composite, which then represents not a specific but a family type—granite. These granite composites may be studied in Plate I. The alkali-granite composite is composed from six analyses, the muscovite-biotite-granite from two, the biotite, hornblende, and augite-granites each from four, so that the family composite is made from the average of twenty analyses.

The composites of each of the families of the igneous rocks having granitic textures may be similarly prepared and studied in connection with one another. (See Plate II). The family types selected, viz., granite, syenite, alkali-syenite, nephelene-syenite, shonkinite, theralite, essexite, diorite, gabbro (including hypersthene-gabbro and norite), pyroxenite, and peridotite, when seen in their composites allow their peculiar characteristics to be read at a glance.

The granites are distinguished from all the other families by their excess of silica and, moreover, by the small quantities of the protoxide bases and moderate amounts of alumina and the alkalies. *The granites, alkali-syenites, and nephelene-syenites form a progressive series which is characterized by decreasing silica and rapidly increasing soda and alumina, and to a less degree by increasing potash and lime, so that the alkali and nephelene-syenite rocks become preëminently the alkali-alumina rocks.*

The shonkonites, theralites, and essexites form a second progressive series in which the silica and iron remain nearly constant but in which the potash, magnesia, and lime steadily decrease as the soda and alumina increase. The essexites are essentially alkali-diorites

JOUR. GEOL., VOL. VIII, NO. 1 Plate III



SOME RARE ROCK TYPES
(GRANITIC TEXTURE)

distinguished from the diorites by a gain of alkalis, lime and iron, and a loss of silica.

The affinities of the syenites are seen to be entirely with the diorites and gabbros, with which they form a third progressive series which is continued imperfectly in the pyroxenites. In this series, characterized by generally decreasing silica and potash, the magnesia, lime, iron, and alumina increase, soda remaining practically constant throughout. The pyroxenites and peridotites, so poor in alkalis and alumina, show close affinity with each other and with the gabbros.

A few petrographical curiosities are represented in Plate III — rocks so exceptional in their occurrence as to be almost or quite unique. The first of these is Rockallite from Rockall Bank in the northeastern Atlantic,[1] a rock of granitic texture chemically closely related to the pantellerites of Fürstner (see Plate VII); Urtite is a nearly pure nephelene rock from the Kola peninsula [2] in arctic Russia which forms the limiting member of the nephelene-syenite family. Yogoite from Montana[3] is a "basic syenite." The "basic nephelene-syenite" from Beemerville, N. J., [4] furnishes the most symmetrical of all the diagrams and gives indication of no near relationship to any other specific rock type though it is classed with the nephelene-syenites. The dunite from Elliott county, Kentucky [5] is so low in silica and so high in magnesia as to be very exceptional, though its diagram conforms to the general shape of the peridotite composite. Ijolite [6] and Missourite [7], the two recently

[1] JOHN W. JUDD: Notes on Rockall Island and Bank (Notice of Memoir) Geol. Mag., Dec., (4), VI, pp. 163–167, 1899.

[2] WILHELM RAMSAY: Urtit, ein basisches Endglied der Augitsyenit-Nephelinsyenit-Serie. Geol. Fören. Stockh. Förh., XVIII, pp. 459–468, 1896.

[3] WEED and PIRSSON: The Bearpaw Mountains of Montana, Am. Jour. Sci., (4), I, p. 357, 1896.

[4] J. F. KEMP: A basic Nephelene-syenite from Beemerville, N. J., N. Y. Acad. of Sci., XI, p. 68, 1892.

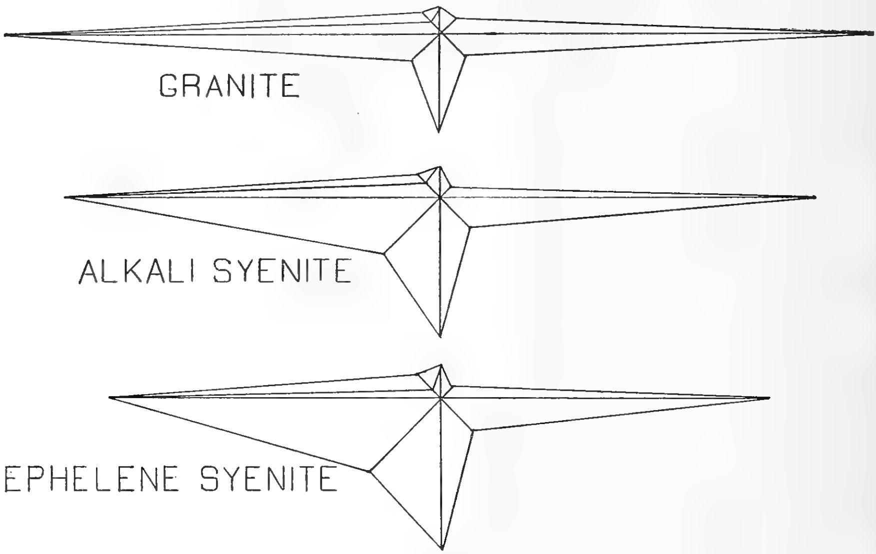
[5] J. S. DILLER: The Peridotite of Elliott County, Ky. Bull. No. 38, U. S. Geol. Survey, pp. 1–29, 1887.

[6] WILHELM RAMSAY: loc. cit.

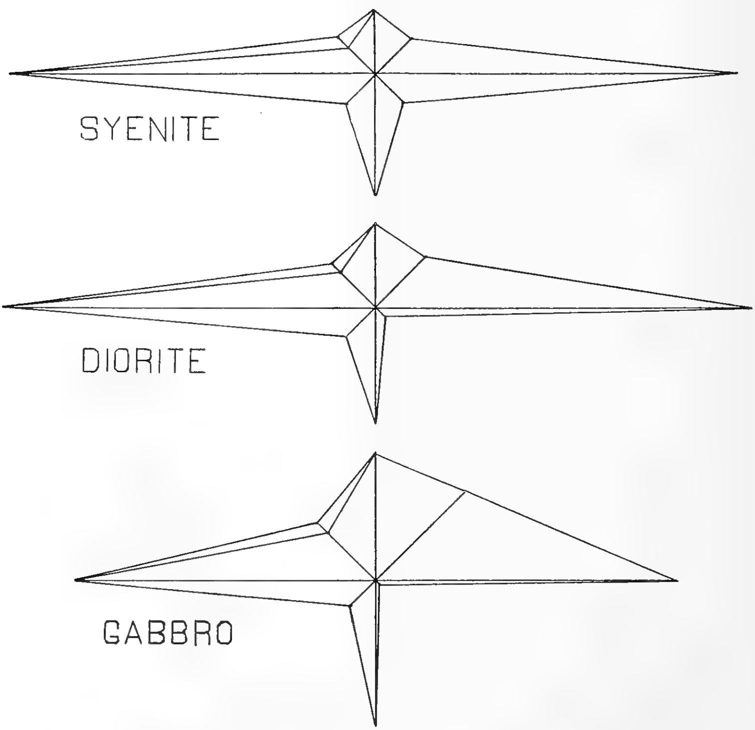
[7] WEED and PIRSSON: Missourite, a New Leucite Rock from the Highwood Mountains of Montana. Am. Jour. of Sci., (4), II, pp. 315–325, 1896.

Jour. Geol., Vol. VIII, No. 1.

Plate IV



GRANITE-NEPH. SYENITE SERIES



SYENITE-GABBRO SERIES

described types for which Rosenbusch has named a new family[1] are certainly remarkable types, but except for the quantities of silica, iron, and lime which they contain, they are as different from one another as two rock types can be imagined to be. Ijolite is rich in soda and alumina, Missourite poor; Ijolite is poor in potash and magnesia, Missourite rich to excess in both. Comparison of their diagrams with those represented in Plate II shows that they are the end members of the Shonkinite-Essexite series, Missourite fitting almost perfectly into the series, being only a trifle low in lime, and Ijolite failing to do so only being too high in lime and a bit too low in iron.

The igneous rocks of granitic texture when examined chemically fall, therefore, quite naturally into three progressive series, which have distinct and common characteristics.—These series may provisionally be designated by the limiting families of each, as the granite nephelene-syenite, missourite-ijolite, and syenite-gabbro series (Plate IV). The peridotites and pyroxenites do not fall perfectly into any of the three, but are yet closely allied to the syenite-gabbro series.

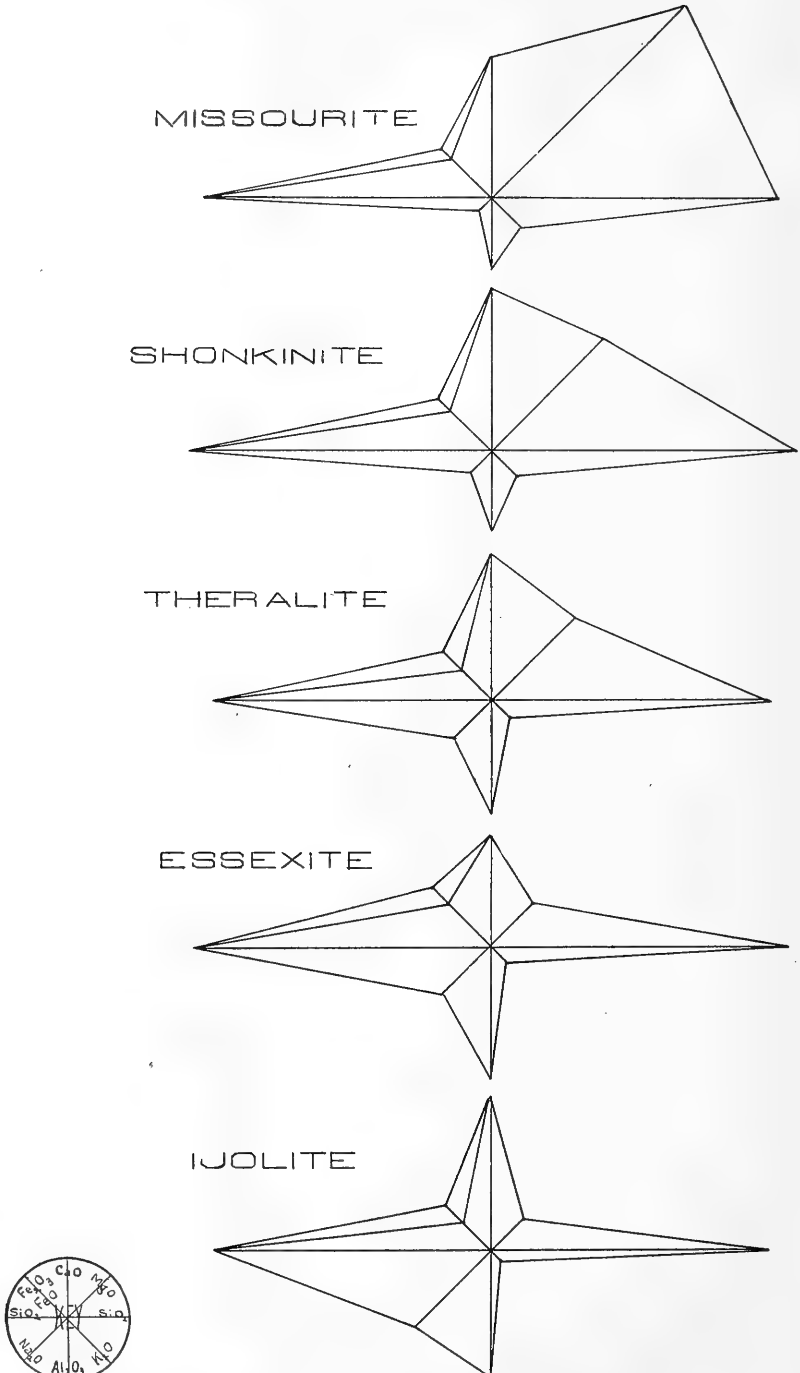
Granite-nephelene-syenite series	Missourite-ijolite series	Syenite-gabbro series
Granite family	Missourite family	Syenite family
Alkali-syenite "	Shonkinite "	Diorite "
Nephelene-syenite "	Theralite "	Gabbro "
	Essexite "	———
	Ijolite "	Pyroxenite family
		Peridotite "

The composite diagrams of the granite-nephelene-syenite and syenite-gabbro series are shown in Plate IV, those of the Missourite-ijolite series in Plate V. The common characteristics of each of the series are well brought out by averaging the composites of the several members in each to form *series composites*, as has been done in Plate VI.

Composites of certain igneous rock types having rhyolitic texture.—No comprehensive attempt has yet been made to determine similar relationships among the rocks of rhyolitic texture, but composites of a considerable number of the specific rock types of

[1] ROSENBUSCH: Elemente der Gesteinslehre, p. 179.

Jour. Geol., Vol. VIII, No. 1 Plate V



MISSOURITE-IJOLITE SERIES

acid and intermediate composition have been prepared. Plate VII displays together the composite diagrams of the specific types belonging to the families which Washington[1] has designated as the trachyte, trachy-andesite, trachy-dolerite, and andesite series.

The rhyolite diagram is a composite of nine analyses of rhyolites from Hungary, Ponza, the Auvergne, Nevada, and Colorado. The soda-rhyolite composite is compounded from six analyses, mainly of Wisconsin rocks soon to be described by C. K. Leith and the writer. The four pantellerites which furnish the pantellerite diagram are from the island of Pantelleria. The trachytes, six in number, are those of the Auvergne, Ischia, the Eifel, the Bohemian Mittelgebirge, and Monte Amiata; and the two domites were from the Auvergne. The vulcanite diagram is not a composite but an individual rock diagram made from the type analysis from Vulcano. The six dacite analyses composed were of rocks from Columbia, Guatemala, Lassen's Peak, Cal., and McClellan Peak, Nev., while the seven andesite analyses used in preparing the andesite composite were of mica- and hornblende-andesites from the Eureka district, Nev.; Custer county, Col.; Cartagena, Spain; the Siebengebirge on the Rhine; Panama; and Columbia. The Toscanite, Vulsinite, and Ciminite analyses are the Italian ones given by Washington,[2] and were respectively ten, ten, and eleven in number. The Banakites, Shoshonites, and Absarokites represented in the analyses are those described by Iddings[3] from the Yellowstone National Park and numbered four, five, and five respectively.

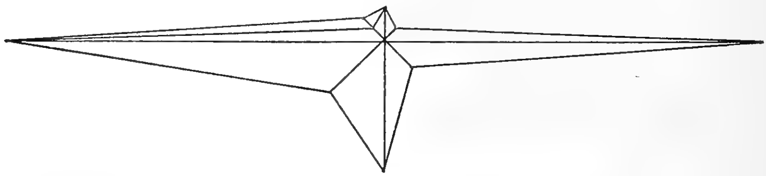
These *specific* composites are much less interesting as indicating relationships than the composites of a higher order would be, but they are here introduced to show that the composite diagram is capable of bringing out the chemical characteristics of rocks which differ only slightly from one another, as well as the characteristics of different families.

[1] H. S. Washington: Italian Petrological Sketches, V. Jour. Geol., V, p. 366. 1897.

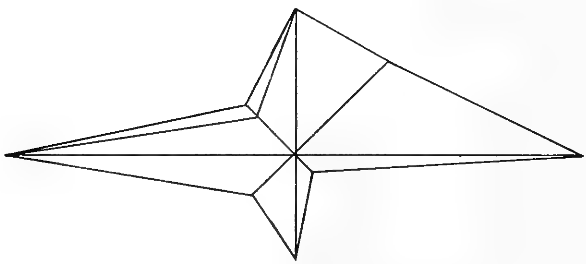
[2] H. S. Washington: loc. cit.

[3] J. P. Iddings: Absarokite-Shoshonite-Banakite series, Jour. Geol., III, pp. 935–959, 1895.

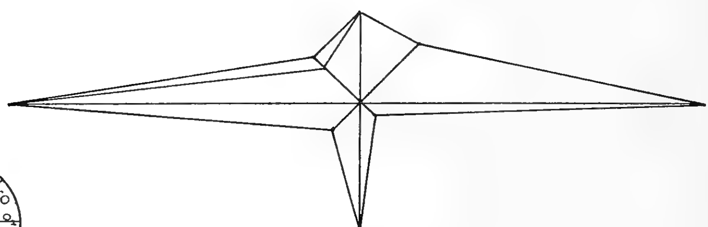
JOUR. GEOL., VOL. VIII, No. 1 Plate VI

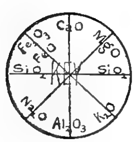


GRANITE-NEPH. SYENITE SERIES



MISSOURITE-IJOLITE SERIES

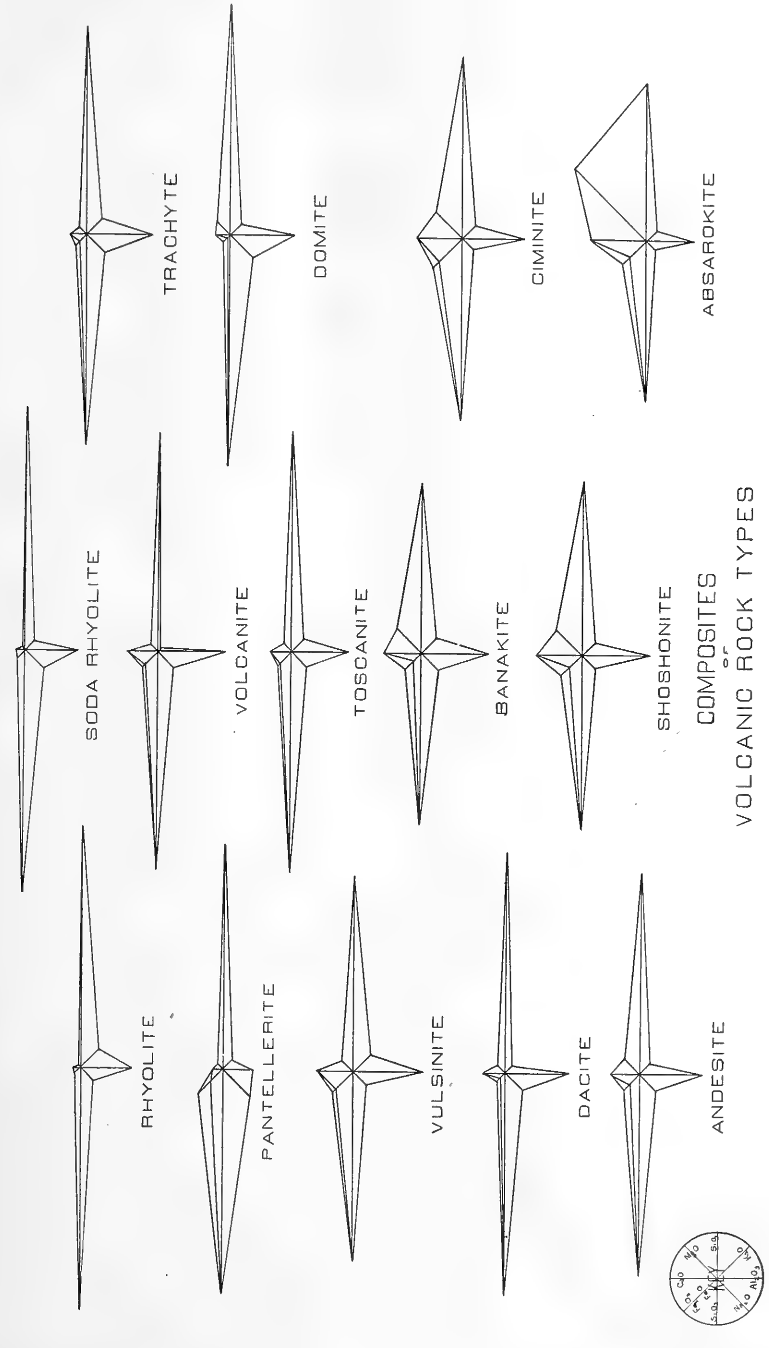




SYENITE-GABBRO SERIES

SERIES COMPOSITES

Jour. Geol., Vol. VIII, No. 1 Plate VII



In conclusion, I would suggest to all persons publishing analyses of rocks the advisability of printing beneath the figures showing the percentage, composition, the corresponding molecular ratios, and further, that the arrangement of oxides in the analysis be for the sake of uniformity that which has been consistently followed by Rosenbusch, Washington, and some others, and which is here used in the composite tables showing the averaging of analyses for the composite diagrams. The principal deviation from this order which I have observed is an inversion of the order of magnesia and lime or of soda and potash, which can hardly be regarded as essential. If these suggestions be followed, the work of those who examine rock analyses will be materially lightened and the liability to error in transcribing will be lessened.

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ROCKS WHOSE ANALYSES HAVE BEEN COMBINED TO PRODUCE THE COMPOSITES OF THE GRANITIC-TEXTURED IGNEOUS ROCKS

The greater number of the analyses of these rocks are to be found either in the tables of Rosenbusch's *Elemente der Gesteinslehre,* published in 1898 (abbreviation R), or in Clarke and Hillebrand's *Analyses of Rocks and Analytical Methods,*[1] published in 1897 (abbreviation C and H).

GRANITE[2]

1. Alkali-granite, Drammen, Norway.
2. Alkali-granite, Sandsvar, "
3. Alkali-granite, Pelvoux, Dauphinée, France.
4. Alkali-granite, Hardwick quarry, Quincy, Mass., Am. Jour. Sci. (4), **6**, p. 181.
5. Alkali-granite, Montello, Wis., Hobbs and Leith. To be described in a forthcoming bulletin of the Geol. and Nat. Hist. Survey of Wisconsin.
6. Alkali-granite, Waushara Co., Wis., Bull. No. 3, Wis. Geol. and Nat. History Survey, 1898, p. 2.
7. Muscovite-biotite granite, Hautzenberg, Bayerischer Wald, Germany.
8. Muscovite-biotite granite, Katzenfels, Graslitz, Erzgebirge, Bohemia.

[1] Bull. 148, U. S. Geol. Surv.

[2] All the granite analyses with the exception of certain of the alkali granites are selected from Rosenbusch's list, on page 78 of the work cited.

9. Biotite-granite, Bobritzsch, Freiberg, Saxony.
10. Biotite-granite, Barr, Alsace.
11. Biotite-granite, Durbach, Black Forest, Baden.
12. Biotite-granite, Melibocus, Odenwald, Hesse.
13. Hornblende-granite, Mariposa Co., Nevada.
14. Hornblende-granite, Pré de Fauchon, Vosges.
15. Hornblende-granite, Syene, Egypt.
16. Hornblende-granite, ("Rapakiwi granite"), Finland.
17. Augite-granite, Laveline, Vogesen.
18. Augite-granite, Oberbruch, Dollerenthal, Alsace.
19. Augite-granite, Kekequabic Lake, Minn.
20. Augite-granite, Birkrem, Ekersund, Norway.

ALKALI-SYENITE

1. Nordmarkite, Tonsenaas, near Christiania, Norway. R. p. 112.
2. Pulaskite, Fourche Mt., Arkansas. *Ibid.*
3. Umptekite, Umpjaur, Kola Peninsula, Russia. *Ibid.*
4. Laurvikite, Laurvik, Norway. *Ibid.*
5. Sodalite-Syenite, Square Butte, Mont. *Ibid.*

NEPHELENE-SYENITE

1. Nephelene-Syenite, Salem Neck, Mass. Jour. Geol. **8**, p. 803.
2. Nephelene-Syenite, Great Haste Island, Mass. *Ibid.*
3. Litchfieldite, Litchfield, Maine. C. & H., p. 65.
4. Nephelene-Syenite, Red Hill, N. H. C. & H., p. 67.
5. Nephelene-Syenite, Fourche Mt., Arkansas. Igneous Rocks of Ark., p. 88.
6. Lujaurite, Umptek, Kola Peninsula, Russia. R. p. 126.
7. Nephelene-Syenite, Beemerville, N. J. C. & H., p. 80.
8. Basic Nephelene Syenite, Beemerville, N. J. N. Y. Acad. Sci. **11**, p. 68.
9. Nephelene-Syenite, Saõ Paolo, Brazil. R. 126.
10. Laurdalite, Lunde, Norway. Zeitsch. f. Kryst. **16**, p. 33.
11. Sodalite-Syenite, Kangersluarsuk, Greenland. R. p. 126.
12. Urtite, Lujaur Urt, Kola Peninsula, Russia. *Ibid.*
13. Leucite-Syenite, Magnet Cove, Ark. *Ibid.*
14. Borolanite, Lake Borolan, Scotland. *Ibid.*

MISSOURITE-IJOLITE SERIES

Missourite

1. Missourite, Shonkin Creek, Highwood Mts., Mont. C. & H. 154.

Shonkinite

1. Shonkinite, Beaver Creek, Bearpaw Mts., Mont. C. & H. p. 149.
2. Shonkinite, Yogo Peak, Little Belt Mts., Mont. *Ibid.*

3. Shonkinite, Square Butte, Highwood Mts., Mont. R. p. 176.
4. Shonkinite, Monzoni, Tyrol. Zeitsch. d. d. geol. Gesell. **24**, p. 201.
5. Nephelene-Pyroxene-Malignite, Poobah Lake, Canada. R. p. 176.

Theralite

1. Theralite, Gordon's Butte, Crazy Mts., Mont. R. p. 176.
2. Theralite, Martinsdale, Crazy Mts., Mont. *Ibid.*
3. Theralite, Umptek, Kola Peninsula, Russia. *Ibid.*

Essexite

1. Essexite, Salem Neck, Mass., Jour. Geol., 7, p. 57.
2. Essexite, Salem Neck, Mass. R. p. 172.
3. Essexite, Isla de Cabo Fria, Rio de Janeiro, Brazil. *Ibid.*
4. Essexite, Mt. Fairview, Custer Co., Colo. *Ibid.*
5. Essexite, Rongstock, Bohemia. *Ibid.*

Ijolite

1. Ijolite, Iiwaara, Finland. R. 180.
2. Ijolite, Kaljokthal, Umptek, Kola Peninsula, Russia. *Ibid.*

SYENITE-GABBRO SERIES

Syenite

1. Mica-Syenite Frohnau, Black Forest, Baden. R. p. 106.
2. Mica-Hornblende Syenite, Silver Cliff, Colo. C. & H., p. 169.
3. Hornblende-Syenite, Plauenscher Grund, Saxony. R. p. 106.
4. Hornblende-Syenite, Biella, Piedmont. *Ibid.*
5. Monzonite, Monzoni, Tyrol. R. p. 109.
6. Monzonite, Yogo Peak, Mont. C. & H. p. 147.
7. Yogoite, Beaver Creek, Bearpaw Mts., Mont. C. & H. p. 156.
8. Akerite, Thingshoug, Norway. R. p. 111.

Diorite

1. Tonalite, Adamello, Tyrol. R. p. 140.
2. Banatite, Dognacska, Ranat, Austro-Hungary. *Ibid.*
3. Grano-diorite, near Bangor, Butte Co., Cal. C. & H. p. 204.
4. Diorite, Elk Mts., Colo., C. & H. p. 177.
5. Diorite, Electric Peak, Yellowstone National Park. C. & H. p. 117.
6. Amphibole-Diorite, Electric Peak, Yellowstone National Park C. & H. p. 118.
7. Augite-Diorite, Electric Peak, Yellowstone National Park. C. & H. p. 117.
8. Augite-Diorite, Peach's Neck, Mass. Jour. Geol. 7, p. 60.
9. Diorite, Schwarzenberg, Vogesen. R. p. 140.

Gabbro

1. Anorthosite, Nain, Labrador. Zeitsch. d. d. geol. Gesell. 1884.
2. Orthoclose-Gabbro, Duluth, Minn. Neues Jahrb. f. Min. 1876, p. 117.
3. Gabbro, Northwestern Minn. C. & H. p. 112.
4. Garnetiferous Gabbro, Granite Falls, Minn. C. & H. p. 113.
5. Gabbro, Nahant, Mass. Jour. Geol. 7, p. 63.
6. Hypersthene-Gabbro, Baltimore, Md. Bull. U. S. Geol. Survey, No. 28, p. 39.
7. Norite, Montrose Point, Hudson River, N. Y. Am. Jour. Sci. (3) **22**, p. 104.
8. Norite, Ivrea, Piedmont. R. p. 151.
9. Forellenstein, Neurode, Silesia. *Ibid.*
10. Forellenstein, Coverack, Cornwall. *Ibid.*

ULTRA-BASIC ROCKS

Pyroxenite

1. Websterite, Webster, N. C. C. & H. p. 92.
2. Bronzite-Diallage Rock, Hebbville, Md. C. & H. p. 84.
3. Hornblende-Hypersthene Rock, Gallatin Co., Mont. C. & H. p. 140.
4. Websterite, Johnny Cake Road, Md. R. p. 165.

Peridotite

1. Mica-Peridotite, Crittenden Co., Ky. C. & H. p. 94.
2. Scyelite, Achavarasdale Moor, Caithness. Quart. Jour. Geol. Soc. **41**, p. 402.
3. Wehrlite, Red Bluff, Gallatin Co., Mont. C. & H. p. 140.
4. Lherzolite, Johnny Cake Road, Baltimore Co., Md. R. 165.
5. Saxonite, Douglas Co., Oregon. C. & H. p. 231.
6. Cortlandtite (Schillerfels) Schriesheim, Odenwald, Hesse. R. p. 165.
7. Bronzite Diallage Peridotite, Howardville, Md. Bull. U. S. Geol. Survey, No. 28, p. 54.
8. Dunite, Dun Mts., New Zealand. R. p. 165.
9. Dunite, Elliott Co., Ky. C. & H. p. 93.

Rare Rock Types

1. Rockallite, Rockall Bank, Atlantic. Geol. Mag. (4) **6**, p. 165. 1899.
2. Basic Nephelene-Syenite, Beemerville, N. J. Trans. N. Y. Acad. Sci. **11**, p. 86.
3. Urtite, Lujaur Urt, Kola Peninsula, Russia. Geol. Fören, Förh, **18**, p. 462. 1896.
4. Ijolite, Iiwaara, Finland, and Umptek, Kola Peninsula, Russia. *Ibid.* **13**, p. 300. 1891.
5. Missourite, Highwood Mts., Mont. Am. Jour. Sci. (4) **2**, p. 315. 1896.
6. Dunite, Elliott Co., Ky. Bull. 38 U. S. Geol. Survey, p. 24. 1887.

COMPOSITES OF IGNEOUS ROCK TYPES OF GRANITIC TEXTURE

	Species of granite					Families of granite-neph.-syenite series			
	Alkali granite (6)	Muscovite-biotite granite (2)	Biotite granite (4)	Hornblende granite (4)	Augite granite (4)	Granite (20)	Alkali syenite (5)	Nepheline-syenite (14)	Composite
SiO_2	74.07 1.226	70.49 1.165	69.43 1.149	69.32 1.147	66.08 1.094	69.88 1.157	60.62 1.004	53.47 .885	61.32 1.015
TiO_2	......	.33	.44	.31	.17	.31	.35	.26	.31
Al_2O_3 ...	13.48 .131	13.77 .135	14.54 .142	13.37 .131	15.81 .155	14.19 .139	19.13 .187	20.87 .204	18.06 .176
Fe_2O_3 ...	1.86 .012	3.69 .024	1.55 .010	1.40 .009	2.12 .013	2.12 .013	2.57 .017	4.93 .031	3.21 .020
FeO	1.29 .018	.02 .000	2.23 .031	2.97 .041	1.30 .018	1.56 .022 3.68	2.09 .028 4.66	1.27 .018 6.20	1.64 .023
MnO.....	......	......	.12	......	......	.02	.10	.07	.06
MgO	.16 .004	.87 .020	.96 .024	1.55 .039	2.17 .050	1.14 .028	.74 .018	.85 .021	.91 .023
CaO.....	.76 .012	1.78 .032	2.94 .053	2.38 .043	2.61 .046	2.09 .037	2.38 .042	2.70 .048	2.39 .043
Na_2O....	4.24 .068	3.82 .062	3.47 .048	2.84 .040	4.36 .061	3.75 .060	6.45 .104	8.26 .133	6.15 .099
K_2O	4.35 .046	4.36 .046	3.91 .042	4.30 .046	4.30 .046	4.24 .045	5.19 .054	5.55 .059	4.99 .053
H_2O	.63	.35	.66	.95	.61	.64	.90	1.32	.95
Others...	......	.18	.05	.50	......	.15	.23	.32	.23
Total ..	100.04	99.66	100.30	99.89	99.53	100.09	100.75	99.87	100.22

COMPOSITES OF IGNEOUS ROCK TYPES OF GRANITIC TEXTURE (*Continued*)

	Families of missourite-ijolite series						Families of syenite-gabbro series			
	Missourite (1)	Shonkinite (5)	Theralite (3)	Essexite (5)	Ijolite (2)	Composite	Syenite (8)	Diorite (9)	Gabbro (10)	Composite
SiO_2	46.06 .762	48.80 .808	44.67 .740	47.91 .793	44.71 .740	46.43 .769	58.73 .972	60.23 .997	48.40 .801	55.79 .924
TiO_2	.73	.59	1.00	1.35	1.41	1.02	.65	.58	.61	.58
Al_2O_3 ...	10.01 .098	11.13 .108	15.58 .151	17.82 .174	17.46 .170	14.40 .141	16.78 .164	16.14 .158	20.06 .196	17.66 .172
Fe_2O_3 ...	3.17 .019 } 8.78	3.68 .023 } 9.16	5.28 .033 } 10.13	5.38 .030 } 11.06	5.15 .032 } 8.86	4.53 .022	3.05 .019 } 6.84	2.69 .017 } 7.20	2.99 .019 } 9.39	2.91 .018
FeO.....	5.61 .078	5.48 .076	4.85 .067	5.68 .079	3.71 .052	5.07 .070	3.79 .052	4.51 .063	6.40 .089	4.90 .068
MnO	......	.07	.11	.02	.20	.08	.14	.02	.04	.07
MgO	14.74 .364	8.41 .210	6.31 .158	3.26 .081	2.67 .060	7.08 .177	2.77 .069	3.62 .090	6.73 .168	4.37 .109
CaO.....	10.55 .189	12.07 .216	11.05 .197	8.29 .148	11.50 .205	10.69 .191	4.82 .086	6.21 .111	9.38 .168	6.80 .121
Na_2O....	1.31 .021	2.33 .038	5.03 .071	5.45 .088	8.73 .141	4.57 .074	3.29 .053	3.40 .055	2.83 .045	3.17 .051
K_2O	5.14 .053	4.54 .047	3.10 .033	2.81 .030	1.82 .019	3.48 .036	4.96 .053	1.74 .019	.88 .009	2.53 .026
H_2O....	1.44	1.31	2.36	1.14	.67	1.38	.96	.58	1.84	1.13
Others...	.81	1.80	.31	.86	.85	.93	.46	.22	.02	.23
Total..	99.57	100.09	99.66	99.97	98.88	99.66	100.40	99.94	100.18	100.14

ULTRA-BASIC COMPOSITES

	Pyroxenite (4)	Peridotite (9)
SiO_2	52.58 .871	40.58 .672
TiO_2	.11	.77
Al_2O_3 ...	3.69 .036	3.64 .035
Fe_2O_3 ...	1.90 .012	5.89 .037
FeO	6.50 .090	5.88 .082
MnO.....	.11	.15
MgO	20.86 .521	30.00 .750
CaO	13.23 .236	5.60 .100
Na_2O....	.22 .003	.47 .007
K_2O	.10 .001	.55 .005
H_2O.....	.57	5.32
Others ...	.50	1.64
Total ..	100.37	100.49

RARE ROCK TYPES OF GRANITIC TEXTURE

	1 Rockallite	2 Basic nepheline-syenite	3 Urtite	4 Ijolite	5 Missourite	6 Dunite
SiO_2	73.60 1.218	41.37 .684	45.28 .749	44.71 .740	46.06 .762	29.81 .493
TiO_2	....	....	....	1.41	.73	2.20
Al_2O_3 ...	4.70 .046	16.25 .159	27.37 .267	17.46 .170	10.01 .098	2.01 .019
Fe_2O_3 ...	13.10 .082	16.93 .106	3.53 .022	5.15 .032	3.17 .019	5.16 .032
FeO	....	....	.49 .007	3.71 .052	5.61 .078	4.35 .030
MnO	.93	....	.19	.20	....	.23
MgO	.11 .003	4.57 .113	.33 .009	2.67 .060	14.74 .364	32.41 .810
CaO	.37 .007	12.35 .221	1.22 .022	11.50 .205	10.55 .189	7.69 .137
Na_2O ...	6.96 .112	4.18 .067	17.29 .279	8.73 .141	1.31 .021	.11 .001
K_2O	....	3.98 .042	3.51 .037	1.82 .019	5.14 .053	.20 .002
H_2O	....	.45	.40	.67	1.44	8.92
Others ...	.06	....	....	.85	.81	7.77
Total ..	99.83	100.08	99.61	98.88	99.57	100.86

COMPOSITES OF ROCK TYPES OF RHYOLITIC TEXTURE

	Rhyolite (9)	Soda Rhyolite (6)	Pantellerite (4)	Trachyte (6)	Domite (2)	Volcanite (1)	Dacite (6)	Andesite (7)	Toscanite (10)	Vulsinite (10)	Ciminite[1] (11)	Banakite (4)	Shoshonite (5)	Absarokite (5)
SiO_2 . .	74.12 1.227	74.50 1.233	68.88 1.140	63.97 1.069	67.54 1.118	66.99 1.109	68.25 1.129	62.16 1.029	67.74 1.121	58.97 .976	56.18 .930	52.06 .868	53.19 .886	49.21 .820
TiO_2 . .	. . . . . .	. . . . . .	. . . . . .	.36	. . . . . .	. . . . . .	. . . . . .	.23	. . . . . .	. . . . . .	.15	.76	.74	.92
Al_2O_3 .	13.21 .129	13.67 .134	8.01 .078	17.62 .172	16.96 .166	17.56 .172	16.35 .160	16.45 .161	14.77 .144	17.84 .174	16.24 .159	17.66 .173	17.81 .174	12.52 .122
Fe_2O_3 .	1.14 .007	1.22 .008	6.72 .042	2.01 .012	2.97 .018	1.41 .008	1.78 .011	3.27 .020	.60 .004	1.67 .010	2.31 .014	4.66 .029	4.25 .026	4.34 .027
FeO . .	.75 .001	1.71 .024	3.37 .047	1.60 .022	.37 .005	3.39 .047	1.19 .016	2.71 .038	3.15 .044	4.67 .065	6.17 .086	2.20 .030	3.07 .043	4.15 .057
MnO . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	.13	. . . . . .	.01	.02	. . . . . .	.03	.23	.13	.11	.13
MgO . .	.15 .004	.24 .006	.62 .015	.92 .023	2.08 .051	.93 .023	1.21 .030	2.20 .055	1.06 .024	1.67 .041	3.95 .098	3.33 .083	3.64 .091	10.36 .259
CaO . .	1.11 .020	1.17 .021	1.46 .026	2.32 .041	2.02 .036	4.25 .076	3.03 .054	4.13 .074	2.99 .053	5.02 .090	6.25 .112	5.11 .091	6.25 .111	8.14 .140
Na_2O .	2.67 .037	3.90 .048	6.78 .094	4.62 .064	4.80 .077	3.35 .054	4.31 .060	4.07 .056	3.25 .052	2.76 .045	2.44 .039	4.09 .057	3.43 .047	2.01 .028
K_2O . .	6.06 .063	2.98 .031	3.35 .035	5.59 .059	3.57 .038	.34 .003	2.48 .026	3.45 .037	4.16 .044	5.86 .060	4.44 .047	5.03 .053	3.88 .041	3.74 .040
H_2O . .	.93	.39	.44	1.14	.39	1.53	1.09	1.15	1.92	1.34	1.59	3.74	2.73	3.96
Others.	. . . . . .	. . . . . .	. . . . . .	.03	.60	. . . . . .	.06	.15	.42	.24	.37	.84	.71	.71
Total	100.05	99.78	99.63	100.18	100.13	99.75	99.76	99.99	100.06	100.07	100.32	99.64	99.81	100.53

[1] The analyses on which this composite is based are too high in alumina and too low in magnesia. Cf. Washington, Am. Jour. Sci. (4) IX, p. 44, 1900.

DENTITION OF SOME DEVONIAN FISHES

During the last few years our knowledge of the multiplicity and relationships of the Middle and Upper Devonian fish-faunas in this country has been enlarged by the discovery of much new material. Exceptionally interesting finds have been made in the Marcellus, Hamilton, and Naples shales of New York, the Chemung-Catskill of Pennsylvania and its presumable equivalent in Johnson county, Iowa, in the Corniferous of Ohio, and in the Hamilton limestone of Wisconsin and adjoining states. From the last-named horizon notable collections have been brought together and rendered accessible for study by Messrs. E. E. Teller and C. E. Monroe and the late T. A. Greene of Milwaukee, and Professors Calvin and Udden of the Iowa State Geological Survey. These have been freely drawn upon in the preparation of the following notes.

GENUS *DINICHTHYS*, NEWBERRY

So intimately related are the two best-known Arthrodires, *Coccosteus* and *Dinichthys*, that the only crucial test of generic distinctness is afforded by the dentition. Likewise, for the discrimination of species, dental characters are all-important. Among the body-plates the chief distinctive characters are furnished by the dorso-median and clavicular.

1. *D. pustulosus* E. (Fig. 1). — Although remains of this Hamilton Dinichthyid are tolerably abundant, nothing was known of its dentition until recently, when one large premaxillary, nearly equaling that of *D. terrelli* in size, and two maxillary or shear-teeth were found by Mr. Teller in the hydraulic cement quarries of Milwaukee. Last fall a fragmentary mandible showing rudimentary denticles along the posterior slope of the cutting edge was obtained from the Hamilton of New Buffalo, Iowa, by Professor Udden, and still more recently Mr. Monroe

was fortunate enough to secure at the typical Milwaukee locality the specimen shown in Fig. 1.

The inner face of this specimen is attached to a block of limestone, a part of the anterior extremity is broken away, and a considerable portion of the posterior end is missing. The total length may be estimated at about 24^{cm}, the proportions being about the same as in *D. curtus*, and about three quarters the size of an adult individual of *D. intermedius*. The posterior

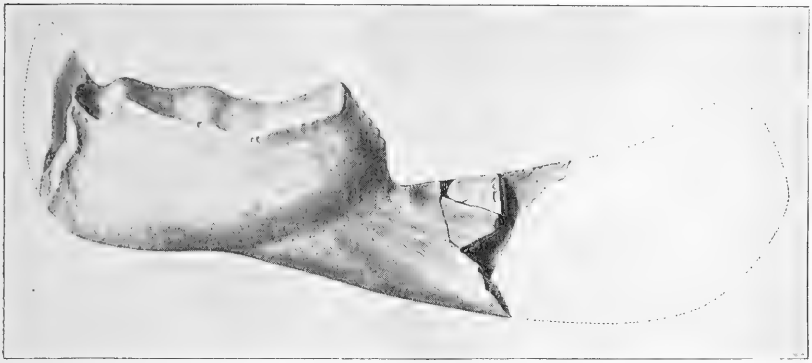

FIG. 1. *Dinichthys pustulosus* E. Hamilton; Milwaukee, Wisconsin. Left mandible. $\times \frac{2}{5}$.

end is more slender than in either of these species, and the cutting edge also differs in having no prominence back of the tooth-like beak. The cutting edge of *D. intermedius* has one such prominence, and that of *D. curtus* two. In *D. curtus* "the posterior end of the cutting edge is set with two or three unequal denticles in place of the series of even, lancet-like points in the same position on the mandible of *D. intermedius*."[1] But in the present form these denticles are reduced to mere swellings, of which five may be counted along the posterior slope of the cutting edge. Professor Udden's specimens, altho smaller, shows the bosses more prominently; they are, in fact, rudimentary denticles, and represent the initial stage of those structures which are such a conspicuous feature in *D. herzeri* of the Ohio Shale.

[1] NEWBERRY, J. S., Pal. Fishes N. A. (Mon. U. S. Geol. Surv., Vol. XVI, p. 156), 1889.

The cutting edge of the mandible is beveled to a sharp edge, and shows the usual indications of wear. It belonged to an average or slightly undersized individual, judging from the proportions of a dozen crania that have been found at Milwaukee. The largest of these, it should be noted, is only one fifth smaller than an averaged-sized head of *D. terrelli*. The premaxillaries and shear-teeth do not call for any special comment, except that the latter are without denticles on the posterior margin.

2. *D. halmodeus* (Clarke).—The presence in the type specimen of functional premaxillary teeth, and of a carinal process on the under side of the dorso-median, are sufficient reasons for transferring this species from *Coccosteus* to *Dinichthys*. The mandibles, which measure about 6.5^{cm} in length, have in place of a cutting edge a series of seven or more backwardly directed denticles. The anterior beak is missing in both mandibles, and the premaxillaries are also damaged. The latter are relatively very powerful, and provided with an elongated base for attachment to the visceral surface of the cranium. The plates designated as *x*, *mx*, *pmx*, and *pto*, in Dr. Clarke's diagram[1] are all parts of a single element, the suborbital. Examination shows that the cranial osteology and structure of the dorso-median are normal in every way.

3. *D. herzeri* Newb.—This species is commonly supposed to be limited to the Huron Shale, but it probably had a continuous range from base to summit of the Ohio Shale. Its occurrence in the Cleveland Shale may be strongly suspected, if indeed it is not proved by two specimens described by E. W. Claypole. The first is the fragmentary mandible known as *D. kepleri* Cl.,[2] and the second is the series of massive plates (plastron and clavicular) preserved in the Ohio State Museum, and figured in part in Vol. VII of the *Ohio Geological Survey Reports* (Pl. XXXVIII–XL). The clavicular and postero-ventro-median each have a length of about 50^{cm}, and the postero-ventro-laterals are over 76^{cm}

[1] Thirteenth Ann. Rep. State Geol. N. Y., Vol. I, 1893, p. 162.

[2] Amer. Geol., Vol. XIX, 1897, p. 322, Pl. XX.

long, indicating a creature about two fifths larger than the average of *D. terrelli*. Believing these proportions too large for any known species of *Dinichthys*, Claypole[1] referred the remains to *Titanichthys;* and later the name of *D. ingens* was suggested for them by Wright.[2] We propose to cancel both this title and that of *D. kepleri* in favor of the type species of *Dinichthys*. Other plates of huge size belonging in all probability to the same species are preserved in the museum of Kentucky State University at Lexington.

4. *D. clarki* (Claypole).—A large species of *Dinichthys* allied to the preceding, so far as may be judged from the dentition, was made the type of a new genus by Claypole,[3] and named by him *Gorgonichthys clarki*. No characters are shown, however, which warrant a separation of this form from *Dinichthys;* on the contrary, the mandible displays an interesting stage of modification between denticulated forms like *D. herzeri*, *D. halmodeus*, etc., on the one hand, and those with a sharp cutting edge like *D. terrelli* on the other.

The type of the so-called "*Gorgonichthys*" and the large premaxillary described by Claypole[4] as *Dinichthys clarki* have, of course, nothing in common. The relations of the latter are not accurately determinable. If excluded from *Dinichthys*, a new generic name will be required; if retained, a new specific name is necessary.

GENUS *CLADODUS*, AGASSIZ

This typically Carboniferous genus occurs sparingly in the Neodevonian, but no species have been reported from Mesodevonian horizons. That it was present, however, in both the Corniferous and Hamilton periods is proved by at least two specimens which have come under the writer's observation. One of these is a large tooth from the Corniferous limestone of Columbus, Ohio, now preserved in the American Museum of

[1] Rep. Ohio Geol. Survey, Vol. VII, 1893, p. 611.

[2] Bull. Mus. Comp. Zoöl., Vol. XXXI, 1897, p. 24.

[3] Amer. Geol., Vol. X, 1892, p. 1.

[4] *Ibid.*, Vol. XII, 1893, p. 278.

Natural History in New York (Cat. No. 4257). Although very similar to *C. striatus* Ag., it probably belongs to a distinct species.

C. monroei, sp. nov. (Fig. 3).—The type of this species is a small, imperfectly preserved tooth found by Mr. C. E. Monroe in the Hamilton of Milwaukee. The drawing reproduced herewith is made up from both halves of the counterpart containing the specimen. Traces of striae appear in places, but are nearly

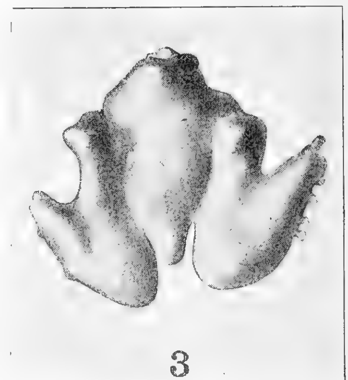

FIG. 2. *Cladodus monroei* sp. nov. Hamilton limestone; Milwaukee, Wisconsin. $\times \frac{2}{1}$.

FIG. 3. Supposed cone-scale from Kinderhook fish-bed at Burlington, Iowa. $\times \frac{2}{1}$.

obliterated by decay of the enamel and dentine, and portions of the crown and base are broken away. The crown is robust, being very thick at the base, and the external denticles are proportionately stout. Three cusps of small size intervene on each side between the principal cone and external denticles. The total height may be estimated at about 1.3^{cm}, and the width of base at 2.5^{cm}.

Other Corniferous forms occurring in the same horizon at Milwaukee are teeth and plates of *Onychodus*, spines of *Machaeracanthus*, and Chimaeroid remains. *Macropetalichthys* and *Asterosteus*, however (which on account of their cranial osteology and lack of dentition we must now exclude from *Arthrodira* and place with the Ostracoderms as degenerate Elasmobranch offshoots), are conspicuously absent.

GENUS *DIPTERUS*, SEDGWICK AND MURCHISON

There are two distributional centers for this genus in America, between which there was apparently no communication. In the eastern province, which includes the Chemung-Catskill of New York and Pennsylvania, it is associated with forms common to the Upper Devonian of Canada and Europe. In the western province (Iowa and Illinois to Manitoba) it ranges from the base of the Hamilton to near the top of the Devonian and is accompanied by *Ptyctodus* and a number of Dipnoan forms peculiar to this region.[1] Here are found no traces of Crossopterygians or Ostracoderms; in fact the western Neodevonian fish-fuana is entirely distinct from the eastern, and represents a different migratory movement.

The Chemung proper contains but two well-recognized species of Dipterus, *D. flabelliformis* and *D. nelsoni*, the latter including Newberry's so-called *D. levis* (founded on worn specimens), and possibly *D. quadratus* and *D. minutus*. From the Catskill of Pennsylvania four species are known: *D. sherwoodi*, *D. fleischeri*, *D. angustus* and *D. contraversus* (= *D. radiatus* N.). Several of these species are founded on imperfect material, and the original descriptions require emendation. To this list may now be added four new species from the Middle and Upper Devonian of Iowa, the types of which are preserved in the Museum of Comparative Zoölogy at Cambridge, Massachusetts.

1. *D. uddeni*, sp. nov. (Fig. 5).—This species is established on a unique mandibular dental plate from the base of the Cedar Valley limestone (Middle Devonian) near New Buffalo, Iowa. It has a total length of 36^{mm}, is moderately convex, and remarkable for the paucity of its denticulated ridges. These are only four in number, and radiate in gently curved lines from the posterior angle, which is worn smooth by use. The anterior row of denticles and inner moiety of the remaining rows are also considerably worn; but in the outer moiety of these rows the denticles are acutely conical, of large size and well separated.

[1] Ann. Rep. Iowa Geol. Surv., Vol. VII (1896), Pl. IV; *ibid*, Vol. IX (1898), p. 302; JOUR. GEOL., Vol. VII (1899), p. 77.

There is a progressive diminution in size of all denticles proceeding posteriorly. The coronal surface is finely punctate.

This beautiful dental plate is the oldest of all *Dipterus* remains that have been found in this country. It was discovered by Professor J. A. Udden of Augustana College, Rock Island, in

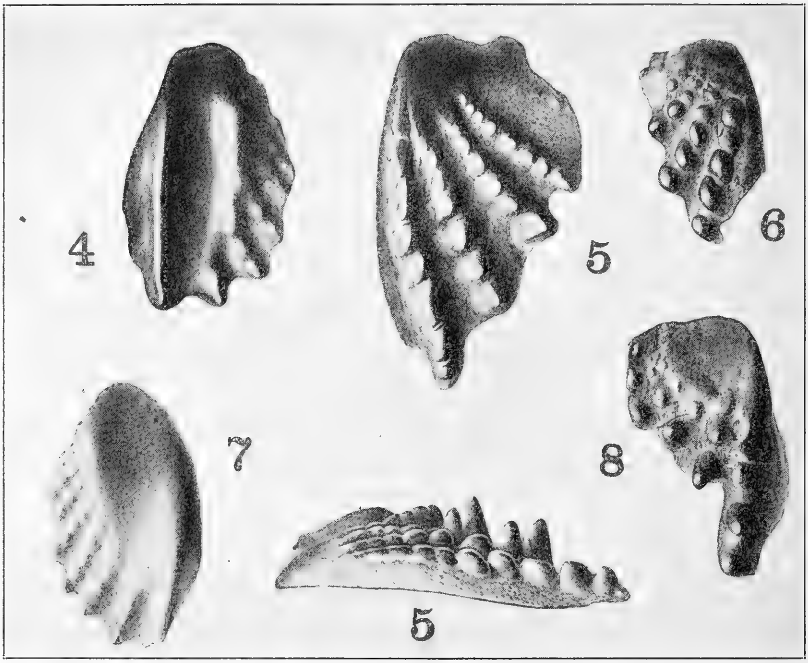

FIG. 4. *Dipterus costatus* sp. nov. Upper Devonian; Johnson county, Iowa.

FIGS. 5, 5[1]. *Dipterus uddeni* sp. nov. Cedar Valley limestone; New Buffalo, Iowa.

FIGS. 6, 8. *Dipterus mordax* sp. nov. Upper Devonian; Johnson county, Iowa.

FIG. 7. *Dipterus calvini* sp. nov. Cedar Valley limestone; Fairport, Iowa.

whose honor the specific title is dedicated. A note of its geological occurrence was published in the August number of this JOURNAL (p. 494) for last year.

2. *D. calvini*, sp. nov. (Fig. 7).—Like the last, this species is founded on a unique dental plate (right mandibular) from the Cedar Valley limestone of Iowa. It comes from a higher level,

however, having been found by Professor Udden in the so-called "Euomphalus bed" at Fairport, Muscatine county, which lies about eight feet below the summit of the Cedar Valley limestone, or Hamilton of Worthen and others.

The plate is elliptical in outline, and moderately convex in an antero-posterior direction. Eight tuberculated ridges extend from the outer margin to about the center of the plate, the two anterior ones being the largest and elevated into a slight fold. Coronal surface considerably worn, and external margin partially broken. Tubercles conical and well separated, except those of the two anterior ridges, which are coalesced and worn on their summits. Total length of plate 3^{cm}. Named in honor of Professor Samuel Calvin, State Geologist of Iowa.

3. *D. costatus*, sp. nov. (Fig. 4).—This plate agrees in size and general outline with *D. calvini*, but it has fewer and more widely separated coronal ridges which disappear before reaching the center of the plate. The distinguishing feature of this species consists in the elevated sharp ridge extending along the entire length of the inner margin, and separated from the remaining tuberculated ridges by a broad longitudinal furrow. This ridge appears to be of compound origin, or made up of three coalesced costae, of which the third counting from the inner margin is the largest. The two innermost costae are so faint as to be almost imperceptible on the steep face of the main ridge. The summit of the latter is sharp, and shows no evidence of being made up of tubercles. The tubercles of the five marginal ridges are also worn nearly smooth and more or less coalesced. But for the convexity (in a longitudinal direction) of the coronal surface this might be taken for an upper dental plate. Several examples of this form have been obtained from the State Quarry fish-bed near North Liberty, in Johnson county, Iowa.

4. *D. mordax*, sp. nov. (Figs. 6, 8).—Dental plate attaining a length of over 3^{cm}, coronal surface gently convex, with six rows of very large, well separated conical or rounded tubercles which extend from the outer margin for a variable distance

toward the posterior angle; the two posterior rows often rudimentary. Some of the tubercles, when worn by use, become elongated in the direction of the rows to which they belong, and others in an oblique direction. This species is readily distinguished from all others previously described by the relative coarseness of its tuberculation. It is represented by a number of examples from the State Quarry beds of Johnson county, Iowa.

NOTICE OF PROBLEMATICAL ORGANISMS

Some thirty years ago Mr. Orestes St. John, when assistant in the Museum of Comparative Zoölogy, collected a number of Selachian teeth and spines and some large Dinichthyid plates from a "fish-bed" near Burlington, Iowa, supposed to be near the dividing line between Upper Devonian and typical Kinderhook. Small spines of *Stethacanthus*, *Erismacanthus*, and *Homacanthus* are rather abundant at this locality, also dermal tubercles of sharks. From the upper part of the formation Mr. St. John obtained the carapace of a Schizopod crustacean, and also some vegetable remains, such as branches of a Lepidodendron and woody fibers. In addition he found a number of peculiar fossils of which the one shown in Fig. 2 is a fair example, and within the past year other specimens of the same sort have been collected by Professor Udden in the Kinderhook near Burlington.

An examination of the latter forms by Professor Arthur Hollick of Columbia College leads him to the opinion that they are cone-scales of some conifer probably allied to *Araucaria*. A figure is given herewith for the benefit of those interested in the study of Mississippian faunas.

EXPLANATION OF FIGURES

FIG. 1. *Dinichthys pustulosus* E. Hamilton limestone; Milwaukee, Wisconsin. Left ramus of mandible. $\times \frac{2}{5}$.

FIG. 2. *Cladodus monroei* sp. nov. Hamilton limestone; Milwaukee, Wisconsin. $\times \frac{2}{1}$.

FIG. 3. Supposed cone-scale from Kinderhook fish-bed at Burlington, Iowa. $\times \frac{2}{1}$.

FIG. 4. *Dipterus costatus* sp. nov. Upper Devonian; Johnson county, Iowa. Left lower dental plate.

FIGS. 5, 5[1]. *Dipterus uddeni* sp. nov. Cedar Valley limestone; New Buffalo, Iowa. Left lower dental plate, oval surface and profile.

FIG. 6, 8. *Dipterus mordax* sp. nov. Upper Devonian; Johnson county, Iowa. Somewhat worn examples of right lower dental plates.

FIG. 7. *Dipterus calvini* sp. nov. Cedar Valley limestone; Fairport, Iowa. Right lower dental plate.

[Figs. 4–8 reduced slightly less than natural size.]

C. R. EASTMAN.

ANCIENT ALPINE GLACIERS OF THE SIERRA COSTA MOUNTAINS IN CALIFORNIA

INTRODUCTION

Northwestern California is a vast complex of mountains, forming the Klamath system, whose geological features are similar to those of the Sierra Nevada range. Centrally situated within it is a series of high granitic and syenitic peaks, constituting the range of the Sierra Costa Mountains. Beginning in Castle Crag, about fifteen miles southwest of the lofty volcanic peak of Mt. Shasta, they trend thence southwestward about fifty miles, with an average width of between fifteen and twenty miles. Within this territory of eight or nine hundred square miles there are a score or more of bare, ragged peaks rising to altitudes of 7200 to 9345 feet above the sea. Between them are deep, narrow valleys whose floors have altitudes between 2500 and 6500 feet, averaging about 4000 feet. Some of the more elevated of these present distinct evidences of past glaciation. The glaciers were very localized in development, never coalescing to form a general glaciation of any part of the territory, and hence the glacial phenomena displayed in these mountain valleys are characteristically different from those of the drift-covered regions of the Mississippi basin.

GENERAL DESCRIPTION OF THE GLACIAL PHENOMENA

There is a radical difference in topography between the glaciated and non-glaciated valleys. The latter are V-shaped gulches with steep straight slopes and a width at the bottom often but little greater than that of the stream flowing within them. In places they are very rocky, with jagged ledges projecting from their sides. All the stony material found on their slopes is of the rock species underlying the soil on each particular slope. The same valley, traced up to where it once possessed a glacier, will rather abruptly change its form to a broad and

open U-shaped trough, with smooth and curved slopes, and a gently rounded floor. This change has been effected by a grinding away of the talus material and solid rock along the middle levels of the slopes and a filling of the extremely narrow lower portion of the gulch. The ravines have been destroyed, partly by filling and partly by the grinding away of the intervening ledges. Often this smoothing of the contours has extended up to a certain level, above which the mountain sides are deeply scored with ravines, and jagged with outcropping ledges.

Most of the valleys present but a moderate amount of ground-moraine, altho the lateral moraines are well developed. The glaciated slopes are abundantly supplied with bowlders of all the rock species occurring from thence to the head of the valley. They are embedded in a loose agglomeration of subangular gravel, sand and a little clay, forming a deposit quite unlike the till of the Mississippi basin, altho somewhat more nearly resembling the very stony moraines of New England. These lateral moraines are smooth in outline, rarely displaying a hummocky topography, and only in a few cases standing out distinct from the mountain ridges. In the unglaciated gulches, especially where the country rock is serpentine, extensive land slips are resting on the lower slopes, and they present a hummocky topography almost identical with that so characteristic of glacial moraines in the Mississippi basin, even to the extent of possessing kettle-holes containing lakelets. These must not be confounded with the lateral moraines.

Lines of erratics perched high on the mountain sides sometimes indicate the maximum altitude of the glacial action. From the smooth curved slopes of the lateral moraines, low narrow ridges of very stony material trend obliquely toward the center of the valley, those on opposite sides forming a loop, pointed downward. Sometimes they coalesce and are then cut by a small canyon-shaped valley thru which the stream finds an outlet from the enclosed basin above. These are the only representatives of true terminal moraines (being formed at successive

stages of readvance during the general recession of the glacier), but are quite insignificant as compared with the lateral moraines.

Near the heads of the glaciated valleys the rock surface is often bare over thousands of square feet, and is then seen to be smoothed and rounded by the grinding action of the ice. Some distinct grooves appear, but are not common. Of more frequent occurrence are fine lines or striæ, altho where long exposed these have been destroyed by weathering.

By far the most characteristic of the glacial phenomena of the Sierra Costa Mountains are the high meadows and lakelets. The former are smooth expanses of the valley floor a mile or more in length by half as great width, occurring near the heads of the valleys. They are inclined to be damp and boggy, and are grassed, instead of timbered and brushy, as other portions of the mountain region. They are underlaid with a fine gravelly silty ground moraine, and over their surfaces are frequently scattered large erratics of an englacial and superglacial mode of transportation. The lakelets are rounded bodies of clear cold water, varying from a fraction of an acre to twenty or more acres in extent, sometimes occupying rock-bound basins of glacial origin, but generally held in behind moraines. Around the border may be a tiny beach of white sand, or a narrow strip of flat, grassy land composed of black peaty soil. Some of these tiny mountain tarns are perched high up on the mountain sides in small coves or niches abraded from the solid rock by the downward pressure of the ice under the *névés*. A few of these coves are hundreds of feet in depth, have steep, often precipitous, rock-walls, and are nearly closed in by the surrounding ridges so that they closely resemble the *cirques* of the Alps.

An especially favorable situation for the glacial lakelets is at the foot of high rock precipices which usually occur on the southern or western sides of the valleys. The glaciers invariably hugged the shady side of the valleys and there accomplished their most active grinding work. It was on the northern side of the frowning peaks that the ice laid longest, and when its final melting

was accomplished, depressions were left at the foot of the precipices which had been produced by the removal of the talus material and some of the solid rock. In several cases one may stand on a high peak and throw a stone so that it will drop into the clear water of a lakelet, 1000 feet below. These high precipices are another characteristic of the glaciated valleys, for they never occur elsewhere in these California mountains.

The glaciers headed in valleys whose altitude is now between 6500 and 7500 feet above the sea, and descended to 5000 or 5500 feet (with two notable exceptions). Thus the declivity of the glaciated valleys is great; but the descent is effected by a series of terraces or steps, gentle slopes alternating with steep, almost precipitous, sections where the valley floor is rapidly let down 100, 200 or even as much as 500 feet vertically. These "steps" are only in small part due to moraines, being composed mainly of solid rock. Over them the glaciers cascaded, forming extensive crevasses, then coalescing into a solid mass and moving along smoothly a mile or more to the next cascade. Toward the close of the ice period, when the main glaciers had shrunk to insignificant remnants, tiny glaciers continued to issue from under the local *névés* in the coves high up on the mountain sides, and cascaded over precipices as much as 500 feet in height.

I have mentioned a sufficient number of the features of these valleys to place it beyond doubt that they have suffered glaciation in some past period, and to demonstrate that the glacial action was essentially identical in character with that at present obtaining in the high Alpine valleys of Switzerland.

CHARACTERISTIC FEATURES OF INDIVIDUAL GLACIERS

The Castle Creek glacier.—At its maximum extension, this glacier had a length of about two miles, a width of one quarter to one half mile and a depth of 500 to 800 feet. It was situated at the northern foot of Tamarack peak, near the junction between Trinity, Shasta and Siskiyou counties. The present altitude is about 6500 feet. Within the limits of its site are six pretty lakelets, one lying at the foot of a 1000-foot precipice. The glacier

flowed in an easterly direction and hugged the southern side of the valley, there leaving the rock bare of talus or morainic material. In receding, it melted away from the warm northern side of the valley, and left several successive lateral moraines on the valley floor, running lengthwise of it. The last of the series is about in the center. A trough shaped depression occupying the southern half of the valley indicates the final track of the dying glacier. In it lie some of the lakelets. A tributary glacier entered the main trunk at nearly a right angle, and cascaded over a rock-ledge now 500 feet above the main valley floor. The ledge is smoothed and striated. Above it a lakelet is held behind a moraine composed of clay, sand, gravel and bowlders, some of which are beautifully striated. The interesting feature of this glacier was its evident sensibility to the sun, causing it to melt away from the sunny side of the valley long before it disappeared from within the shadow of Tamarack peak.

The Salmon River glacier.—This was seven miles in length, one half to one mile in width and 1000 to 1500 feet in depth. Its course was a little east of north. It headed at about 6500 feet of altitude (present), and descended but little below 5500 feet. On the west of its upper half was the high granite peak of Mt. Courtney, whose slope is now bare of loose rocks and soil from summit to base and is worn smooth and rounded by glacial abrasion. From the precipitous pinnacles of the sawlike crest, huge bowlders of granite crashed down upon the ice, and now lie scattered upon the floor of the valley and even over the opposite slope. Several are as large as an average miner's cabin. Beyond the granite of Mt. Courtney, where the rocks are mainly hornblende and mica schists, the upper limit of the glacier is clearly defined high on the mountain sides by a sharp line below which granite bowlders are numerous and above which there are none; also, by shoulders or small precipices on the inter-ravine spurs of the mountain on the east, showing to what height the glacial abrasion extended.

Many prospectors and semi-scientific observers have noted the fact that the upper four or five miles of the original main

Coffee Creek has been beheaded and added to the South Fork of Salmon River, but not many have clearly discerned that this was due to glacial action. In ascending the Upper Coffee Creek valley, after the great bend is passed, the floor widens to quite a plain, there being here a heavy filling of waterlaid gravel and sand, the extra-glacial deposit of the glacier above; on this, at the mouth of each tributary gulch, there is a beautiful alluvial fan. About one and one half miles below the head of the creek, a slight ridge crossing the valley and carrying granite erratics marks the extreme limit of the glacier. From here to the summit stretches the "Big Flat," a smooth plain of fine gravel and sand (with scattered granite erratics) about one and one half miles in length and one half mile in width. At its upper end (which is the summit of the Sierra Costa Mountains, the water-parting between the main Klamath and the Trinity River systems, and the Trinity-Siskiyou county line) there is the slightest tendency to a morainic character. This "Big Flat" has an altitude of 5500 feet while the mountains on either hand rise to 7000 and 7500 feet. Here the glacier made a filling several hundred feet in thickness, thus obstructing the valley. At the same time it wore the rock wall of the valley on the west (which had already been nearly cut thru by the head water erosion of the original South Fork of Salmon River) so thin that a glacial stream crossed the ridge in a col and soon cut down a gorge. Hence it is that the South Fork of Salmon River rises in the head of the original Coffee Creek valley, follows it for four or five miles until within a few hundred yards of the present head of Coffee Creek, then turns to the west at a right angle, and passing out of the broad valley thru a narrow gorge where it abounds in rapids and falls, it makes its way thru unglaciated gulches to the Klamath. This is one of the finest examples of the beheading of a stream by glacial action that I know of.

As indicated by the granite erratics, the surface of this Salmon River glacier descended 1000 feet (and the glacier thinned to that amount) in the last one and one half miles of its course.

Within several miles of its head, the South Fork of the Salmon River has carved a pretty postglacial gorge or tiny canyon in the solid rock of the old valley floor. This is twenty to thirty feet in depth, has precipitous walls, and is no wider than the small stream flowing in it. It abounds in rapids and low cascades.

The Union Creek glacier.—This occupied the next main series of high valleys to the east of the Salmon River glacier. There was a main trunk five miles in length, and two branches each several miles in length. The width was one quarter to one half mile, and the thickness of all approximated 1000 feet. They headed at about 6500 feet (present altitude), and the main trunk descended to 5000 feet of altitude. Near its end it was much contracted, and but little modified the original V shape of the valley. Its extent is clearly defined by its very bowldery lateral moraines. One of these partly obstructs the mouth of a tributary valley, that of Pin Creek, which was not glaciated, altho equally as elevated as glacier occupied valleys on either side of it. This was because it opened too directly toward the sun.

When recession had proceeded to the extent of dissevering the branches of the glacier in the East and West Union Valleys, that of the East Union was the most vigorous, and formed a beautiful half-looped terminal moraine at the junction. The West Union Creek flows swiftly in a shallow ditch cut into the very bowldery deposit just outside of the crest of the moraine, but transverse to the general slope of the surface. This shows that this creek occupied its present course as early as the time when the moraine limited the East Union glacier. The extremely small amount of erosion accomplished on this steep declivity tells of the recency of the glacial epoch in these mountains.

The three Unions have the usual meadows, and are well supplied with glacial lakelets.

The Swift Creek glacier.—The characteristic features of this member of the glacial series were its length, its descent to a low

altitude, its heavy ground moraine, and its beautiful terminal moraine.

At its maximum extension, this glacier had a length of not less than fifteen miles, a width of one half to one mile, and a depth of 1000 to 1500 feet. It was the largest single mass of ice, so far as I know, of the Sierra Costa Mountains. It headed among the peaks in the highest portion of this range, at an altitude now about 6500 feet, trended in an easterly direction, forming the broad flat of the Mumford meadows (altitude 5500 feet), then ran southeasterly, descending rapidly to a level now little more than 3500 feet above the sea, where at ten miles from its head, it suddenly issued from the high mountains, and turning to the northeast, it deployed upon and across a broad basin valley of Miocene age and later, and terminated very close to the site of the Redding and Trinity Centre road at an elevation now no greater than 2500 feet above the sea. Here are, so far as I am aware, the least elevated direct glacial deposits west of the Sacramento River, if not in the whole state of California.

Among the prospectors of northern California, the "cemented gravel of Swift Creek" is a term to conjure with. It is essentially non-gold-bearing, and so far as the ability of the average miner to sink a shaft through it is concerned, it is bottomless. It is an unstratified agglomeration of bowlders, cobbles, pebbles, sand, silt, and clay, which occupies the valley from head to mouth, forms the flats or meadows, and is trenched by a narrow canyon carved by Swift Creek in postglacial time. Where the stream, in undermining a bank, has made a recent excavation, the deposit has an extremely fresh appearance and a delicate light bluish tint. Many of the included bowlders are rounded and polished, and not a few are beautifully striated. It is as typical a till as any to be found on this continent. Being largely the result of glacial abrasion on the rock floor and walls of the valley (serpentine mainly), it is slightly cemented by the large constituent of unoxidized magnesian and calcareous salts. Most of the included rock fragments are serpentine of the black

amorphose variety, and the light oil-green schistose variety, and the blue tinting was derived from the grinding of this formation. It cannot be worked for its included gold as a placer deposit, because there has been no concentration of the precious metal by water action as in ordinary stream alluvium.

This fine deposit of subglacial till or ground moraine attains its fullest development about midway of the course of the glacier where it must have a depth in places of not less than several hundred feet. At an altitude of about 5000 feet, the most prominent glacial features cease. Beyond this the valley contracts and descends rapidly over a series of high steps, which are strewn with a profusion of bowlders, some of which are striated. Everything here is confusion — there may be indistinct terminal moraines, lateral ridges, *roches moutones*, and some ground moraine, but the best expert cannot get much regularity out of the piles of bowlders heterogeneously distributed along the slopes of the bounding mountains and on the irregular valley floor. Here the creek descends rapidly in one long series of rapids and cascades, along its bowlder strewn bed, and in one place has cut a beautiful gorge thru the solid serpentine rock. It is several hundred feet in length and thirty to fifty feet in depth, and no wider than the stream. With its perpendicular and even overhanging walls, it is a veritable canyon. It abounds in *remolinos* (pot-holes) whose mode of formation can plainly be seen, from the clearness of the water.

When the Swift Creek glacier issued from the deep valley in the high Sierra Costa Mountains and deployed across the Miocene basin, it did not spread out as an alluvial delta, but it maintained its narrowness to the end, five miles distant. Around this extra-montane portion it formed a beautiful moraine. The constitution of this is essentially similar to that of the cemented gravel farther up the creek, except that it contains less clay, is looser and coarser in texture, and has some large erratics on its surface. Where trenched by tributary creeks and its interior freshly exposed, polished and striated pebbles and bowlders are not difficult to find. Two parallel ridges of about equal height,

and even crests, trend from the sides of the mouth of the upper valley northeastwardly across the Miocene basin, gradually descending toward Trinity River. Between them is a flat-bottomed, steep sided depressed area, 300 to 500 feet in depth and one half mile in width, evidently representing the cross-section of the glacial tongue. From the crests of the ridges more gentle slopes of very bowldery land extend outward and gradually merge with the erosion surface. These ridges are the extra-montane extensions of the lateral moraine, but also contain ground moraine and may be considered a terminal moraine. Near the Trinity River they flatten down, become hummocky and indistinct, but appear to curve around the end of the site of the ancient glacier and connect, except for the postglacial canyon which the stream has cut thru the moraine. Beyond this is a fine example of a fan-shaped extra-glacial delta, which occupies several square miles in the valley of the Trinity River, and its outer edge descends almost to the level of that stream itself.

This glacial tongue reached the northern end of the low Minerva range of mountains, and built its moraine across the mouths of several of the gulches. These have been filled nearly to the level of the moraine summit by fine silts, and form extensive grassy flats composed of deep black soil free from pebbles. Along the moraine the flats have some large angular erratics on their surface; these have slidden from the surface of the glacier.

In the bottom of the depressed area within the moraine Swift Creek has eroded a canyon 75 to 150 feet deep and 300 to 500 feet wide, widening and shallowing toward the mouth. This seems large, but represents glacial as well postglacial stream erosion.

On the whole, the glacial features of the Swift Creek valley are extremely interesting and instructive, and, from its accessibility, should become classical among students of California Quaternary geology.

The East Fork glacier.—This occupied a high valley, steeply descending on the east face of Granite Peak, a few miles northwest of Minersville. Near its head a precipitous mountain side

shows the smoothing and rounding action of the glacier up to a certain height, above which the bare rock is extremely rough and jagged. Some glacial grooves are seen and a little striation. In another place there is a well-defined line of perched erratics.

This glacier also issued from the high mountains, and it cut directly thru the old Miocene river channel, carrying its huge granite bowlders nearly or quite to the Minersville-Trinity Centre road, terminating at a point probably now no greater than 3000 feet of altitude. It is a well-known fact that all the gulches which are cut into this old Miocene channel deposit have been rich in placer gold, except the valley of the East Fork, which cuts directly thru it, and yet never paid to work. The apparent anomaly is explained when it is understood that the East Fork glacier ground all of the gold-bearing alluvium out of the valley and left in its place its own only slightly auriferous deposit—the glaciated valleys are never worked as placers.

Quite a number of other valleys in the Sierra Costa Mountains were once occupied by glaciers. The presence of a number of lakes (as mapped) in the deep canyons south and east of Mt. Thompson of the granite Cariboo range seem to indicate that a cluster of them occupied that region. Probably a score or more existed in Trinity county alone; but the examples given in this paper are typical of them all, and will suffice for the purposes of the present study.

THE AGE OF THE GLACIERS

At one time I thought I had detected evidences of two glacial epochs in the Sierra Costa Mountains, one very recent and another much older, but I have had to revise this opinion. The deposits near the lower end of the glaciated valleys are of slightly more aged appearance than those near the heads, but the contrast is not great. They are essentially a unit, so far as age is concerned.

The weathering of the once striated, polished, and perfectly smoothed rock surface, the erosion of small canyons in the rock-floors of several of the glaciated valleys near their heads, and

the peaty accumulations about the borders and on the bottoms of the lakelets show that the glaciation has not just terminated—the ice has been completely gone for at least several thousand years. Yet the many lakelets held behind frail barriers of till, the cascades and rapids, and the generally uneroded condition of the drift tell, in unmistakable terms, of the comparative recency, geologically speaking, of the glaciation. Subaerial erosion, aside from one main stream channel in each valley, has been practically nothing. Even the excavation of the single central canyon was largely accomplished while the ice yet lingered in the heads of the valleys, and by its rapid melting greatly increased the streams. With the steep declivities and the heavy annual precipitation, it is remarkable how little erosion has been accomplished in northwestern California since the glacial epoch. Certain cemented river gravels in the valleys of the East Fork of Trinity River, the main Trinity River, and lower Coffee Creek, which represent the outflow from the glacier, rest upon the lowest bedrock in these valleys, and the canyons since excavated in them are quite insignificant. Glaciation was one of the very latest events in the northern California valleys. That it was of late Quaternary age requires no argument.

The beautiful sky-blue till of the Swift Creek valley has a freshness which may be likened unto that of the Wisconsin drift-sheet in the Mississippi basin, and oxidation of its surface portion has not proceeded to any greater depth. Indeed, the youthful appearance of the whole series of glacial phenomena is identical with that which has come to be associated in my mind with the Wisconsin drift sheet. I am certain that this Sierra Costa glaciation was not the age equivalent of the Iowan or any earlier drift sheet. I am equally as certain that the glaciers disappeared a sufficient length of time ago to carry the glaciation back to the Wisconsin epoch. If there were two Wisconsin glaciations in the Mississippi basin, as some glacialists seem inclined to conclude, this California glaciation represented the later. At any rate, the glaciers of the Sierra Costa Mountains certainly were of Wisconsin age.

DISCUSSION OF CLIMATIC CONDITIONS DURING GLACIATION

It goes without saying that it was cold and there was much snow. But under this heading I wish to argue that there was no difference in the *character* of the climate between that and now—merely a lowered annual temperature and probable increased snowfall. The present climate of the Sierra Costa Mountains partakes of the general equability of the Pacific Coast region, but in addition possesses a typical alpine character. A strong contrast between the heat of night and day, *and between that of light and shadow*, is a characteristic of high altitudes where the atmosphere is clear and light, and radiation rapid. One may suffer from the heat in toiling up a sunny slope, while the air in the shadow of a peak may seem almost freezing cold. This is the condition of today at the higher levels of the Sierra Costa Mountains, and the behavior of the glaciers indicates that the same obtained in their time. They were unusually sensitive to sunlight, and shrank into the shadow of the peaks.

Gulches which faced the sun were unglaciated, altho perhaps surrounded by others in which ice accumulated to a depth of over 1000 feet. In fact, shadow was as much one of the necessary conditions of glaciation as cold and snow fall. This shows that the climate possessed the same alpine character as today. I am strongly impressed that the evidence indicates an altitude for these mountains during the Wisconsin epoch, at least as great as the present.

A POSSIBLE CAUSE OF THE GLACIAL PERIOD IN THE SIERRA COSTA MOUNTAINS

I am not prepared to argue conclusively as to why these glaciers formed in the elevated valleys of the northwestern California mountains; but I wish to present, in closing this paper, what I conceive to be a possible explanation of their existence, an hypothesis sufficient to account for all their phenomena.

The valleys where the ice accumulated are all above 6000 feet of altitude, and the sites of the main *névés* approximate a general elevation of 6500 feet above the sea. Even today the

climatic conditions at this altitude are not far removed from those favoring glaciation. The winter snow fall on the mountains is heavy, they being near the coast. On the higher peaks, light flurries of snow are often seen in July, and by the end of October, the winter's snow has set in in earnest. Storm after storm ensues thruout the winter and well on into the spring. By April 1 it is no uncommon thing for the higher mountains to be sheeted under eight, ten, fifteen, or in places as much as twenty feet in depth of well-packed snow. This melts away slowly. By June, most of it is gone; by July, nearly all; but some remains all the year on the northern slopes of Mt. Thompson and Granite Peak and in sheltered ravines of Mt. Courtney. This perennial snow lies at altitudes of about 8000 feet.

Now, in my opinion, a general uplift of the entire region to the extent of 3000 feet would be a sufficient cause for the duplication of the ancient glaciers and a restoration of the whole mountain range to its condition in the Wisconsin epoch. That would carry the summits of all the peaks above 10,000 feet, elevate the main ones, such as Granite Peak and Mt. Courtney, to 11,000 and 11,500 feet, and Mt. Thompson would tower to the altitude of 12,345 feet, comparable with Mt. Shasta. The heads of the glaciated valleys would be elevated to 9500 feet. If perennial snow lies today in small ravines at 8000 feet, how readily must it have accumulated in deep valleys over 1500 feet higher and in the shadow of peaks towering to 11,000 and 12,000 feet. Considerable bodies of snow lie all the year at no greater altitude on the sunny side of Mt. Shasta, and one may see snow on any summer day by glancing at Lassen Peak whose altitude does not much exceed 10,000 feet. Both these mountains are far from the coast, in a comparatively dry belt.

From their nearness to the Pacific Ocean, the elevated Sierra Costa Mountains must have received a heavier snow fall at a given altitude than Mt. Shasta. Also, being a group of mountains (acting like an elevated plateau) instead of a single isolated peak must have favored a lowering of the temperature and increased precipitation. Even without an added snow fall, a

simple elevation would not fall far short of reproducing the glaciers. But as the result of the uplift, it is safe to count on a greatly increased precipitation. It appears to me evident that the present conservative estimated average for the higher regions of ten feet annually might be doubled. Of this amount one half, or ten feet in thickness, might melt from the surface of the *névés* during each summer (the sun finds difficulty in removing that amount even at present altitudes). The remaining ten feet might compact into one foot of ice. Were there no loss by outflow and melting at the end of the glacier, the accumulation of one foot of ice annually would reproduce the large Salmon River glacier in 1500 years.

But a large part of the ice moved outward beyond the zone of accumulation and was lost by melting. This loss was partly compensated for by heavy snow-slides from the surrounding precipitous peaks; yet, with the greatest latitude, we must allow two or even three times as great a period as that first mentioned for the accumulation of the glacier, and the attainment of its maximum extent. I consider 5000 years as a fair estimate, and one which is not too strongly open to criticism. By a lowering of the altitude to the present and consequent increased mildness of the climate (in other words, a restoration of present climatic conditions), probably about half that time or 2500 years would be sufficient to cause the disappearance of the glaciers, and give time for the repeated slight readvances which marked their recession.

The preceding is intended merely as a suggestion, a hypothesis worthy of serious consideration. The demonstration of its reliability will depend upon external evidence of the supposed temporary uplift of these mountains. This can only be secured by careful geological work between this range and the sea, which has not yet been done.

The importance to glacialists in general of studies on the localized Quaternary glaciers of limited mountain districts lies not so much in the contrast between their alpine features and the continental features of the great North American and

European ice sheets, as in the bearing which they may have on the fascinating and yet unsettled question of the "Cause of the Glacial Period." After trying unsuccessfully to solve the problem through a study of the varied series of drift sheets in the Mississippi basin, I have concluded that we will do well to take into account such evidence as may be gathered in alpine regions of glaciation—outlines of the main sheets, we may say—for here the problem of determining climatic changes is less obscure. The suspicion is growing in my mind that the "Glacial Period" in geology, as a glacial or relatively cold epoch of time, was of world wide extent in its effects, and the absolute determination of the cause of the past accumulation of glacial ice in one section will be the key to the solution of the problem of all terrestrial glaciations.

OSCAR H. HERSHEY.

November 18, 1899.

AN ATTEMPT TO TEST THE NEBULAR HYPOTHESIS BY THE RELATIONS OF MASSES AND MOMENTA

In a paper entitled "A Group of Hypotheses Bearing on Climatic Changes,"[1] read before the Geological Section of the British Association for the Advancement of Science at the Toronto meeting in 1897, I assigned reasons for doubting the Laplacian hypothesis of the origin of the solar system, based on deductions from the kinetic theory of gases. These doubts had arisen in the course of certain atmospheric studies springing from the problem of ancient glaciation. The complete demonstration by the geologists of the far Orient that extensive ice sheets developed on the borders of the torrid zone in India, Australia and South Africa during a late stage of the Paleozoic era had made it imperative to seriously reconsider inherited views relative to the nature of the earth's early atmospheres, and this in turn forced an inquiry into the current postulate of a primitive, vast, gaseous envelope exceptionally rich in carbon dioxide; for the special heat-absorbing qualities of this constituent render it doubtful whether its presence in large amount is compatible with glaciation. The inquiry led to the application of such tests as could be derived from the doctrine of molecular velocities. As the result of such application it appeared quite impossible that a hot gaseous ring formed of the matter of the earth and moon, and having the dimensions postulated by the Laplacian hypothesis, could retain its water vapor and atmospheric gases, for its gravitative control over these was found to be far below what was necessary to overbalance their molecular velocities. It appeared very doubtful whether any of the matter of the ring, even that having the lowest molecular velocities, could be retained at the postulated temperatures and tenuity. The test seemed altogether decisive against the Laplacian hypothesis if the kinetic theory be true and the computed

[1]Published in full with supplementary tables in the JOUR. GEOL., Oct.–Nov., 1897, pp. 652–683.

molecular velocities essentially correct. However, the kinetic theory is perhaps not yet beyond its trial stages, though it is probable that the essential postulates involved in the doctrine of molecular velocities are true whatever the precise interpretation of the facts may be. There is an accord between the doctrine and the facts in the solar system which strengthens this conviction. There is an absence of atmosphere from all satellites and asteroids, so far as can be determined. The planet Mercury has little or no atmosphere. The small planet Mars has but a thin atmosphere. The Earth and Venus have considerable gaseous envelopes, while Jupiter and Saturn appear to have vast and deep atmospheres ; in short, there is a general correspondence between the mass of the atmosphere and the gravitative competency of the body. In still further evidence is the essential absence of the lightest gases, hydrogen and helium, from the earth's atmosphere.[1] The former, to be sure, is chemically active, but the latter is very inert.

Notwithstanding the apparent strength of the molecular argument, other tests, based on quite independent grounds, are desirable. The more is this true since a modification of the form of the Laplacian hypothesis in which a lower temperature and a meteoroidal state are postulated deprives the molecular argument of much of its bearing. It is true that this change in the hypothesis when carried out consistently in its full application permits, if, indeed, it does not require, a revision of some of the fundamental doctrines of current geology, such as the former molten state of the earth and the long train of doctrines that hang upon this. So profound is the influence of this primal conception of a molten earth upon the dynamical conceptions and historical interpretations of the earth's evolution that every source of light bearing upon it has an importance we can scarcely realize at present.

[1] "On the Cause of the Absence of Hydrogen from the Earth's Atmosphere and of Air and Water from the Moon," by Dr. Johnstone Stoney, Royal Dublin Society, 1892. Also "Of Atmospheres upon Planets and Satellites," by the same, Trans. Roy. Dublin Society, Vol. VI, Part 13, Oct. 25, 1897; also "A Group of Hypotheses Bearing on Climatic Changes," by T. C. Chamberlin, JOUR. GEOL., Vol. V, No. 7, Oct.–Nov., 1897.

The laws of dynamics afford a firm ground of inquiry so far as they can be brought into service. As applied to mass and momentum they are rigorous, and so far as they can be covered by satisfactory computation they are decisive. The purpose of the present paper is to set forth the results of an attempt to apply these laws to the nebular hypothesis in certain ways that are more or less unfamiliar. These results are the outcome of a joint inquiry by Dr. F. R. Moulton and myself. They are a part of the results of a more or less continuous study on related themes lying on the border-land of geology and astronomy, running through the past three years. Our relations have been so intimate and our exchanges of ideas so free and so frequent that it is impossible to apportion the responsibility for the various methods adopted and the modes of carrying them out. The higher mathematical work is, however, to be credited to Dr. Moulton. It has perhaps been my function in the main to formulate problems and suggest general modes of attack, and Dr. Moulton's to devise methods of analysis and bring to bear the mathematical principles of dynamics, but this has not been uniformly so. Quite often we have proceeded by successive alternate steps in which each was the parent of its successor. In a paper in the *Astrophysical Journal* published essentially concurrently with this, by mutual understanding, Dr. Moulton discusses not only the bearings of the ratios of masses and momenta treated in this paper, but several other modes of testing the nebular hypothesis, some small part of which have been touched upon in my previous papers and some of which will be discussed in these pages later. The mathematical treatment of the present theme will be found in Dr. Moulton's paper.

For convenience and definiteness, the treatment here will be based on the Laplacian phase of the nebular hypothesis, but the conclusions will be found applicable, in all essential respects, to such meteoroidal modifications of the hypothesis as postulate a spheroidal form controlled by the laws of hydrodynamic equilibrium.

1. *Comparison of the moment of momentum of the nebular system with the moment of momentum of the present system.*—It is a firmly established law of mechanics that any system of particles of any kind whatever rotating about an axis retains a constant moment of momentum whatever changes of form or arrangement the matter may undergo by virtue of its own interaction. To make this law rigorously applicable to the solar system evolving along Laplacian lines, the influence of external and of incoming bodies must be excluded. Foreign meteoroidal matter has doubtless been added constantly to the system during its evolution, but the amount of this is assumed to be negligible; and if it were not, the law of probabilities would render its effect upon the rotation of the system an essentially balanced one, and hence immaterial. The following argument proceeds upon the Laplacian assumption that the system evolved through the operation of its own inherent dynamics. On this assumption the sum total of rotational and revolutionary momentum must have been the same at all stages of the system's evolution.

The following table gives the masses and the present moments of momenta of the several members of the solar system and of the whole system. They are taken from Darwin's paper, "On the Tidal Friction of a Planet attended by several Satellites and on the Evolution of the Solar System,"[1] and are employed in the subsequent computations. The masses assigned the planets embrace those of the attendant satellites.

Body	Masses (Earth 1)	Moments of Momenta (Darwin)
Sun	315,511.00000	.444 Laplace's density law (Min.) .679 Homogeneous density (Max.
Mercury	.06484	.00079
Venus	.78829	.01309
Earth	1.00000	.01720
Mars	.10199	.00253
Jupiter	301.09710	13.46900
Saturn	90.10480	5.45600
Uranus	14.34140	1.32300
Neptune	16.01580	1.80600
Solar System	315,934.51422	22.53161 (Min.) 22.76661 (Max.)

[1] Phil. Trans. Roy. Soc., Part II, 1881, pp. 516, 517.

The distribution of density in the sun is unknown. If it follows Laplace's law the rotatory momentum is .444. If it be regarded as homogeneous, the rotatory momentum is .679. This latter is certainly too large, and the former number is probably much nearer the truth, but the larger number is used in the greater part of the computations because it is more favorable to the Laplacian hypothesis.

To obtain the rotatory momentum of the ancestral nebula it is necessary to consider its form, extent, and the variation of its internal density. By hypothesis the form was an oblate spheroid, but the exact degree of polar flattening is unassigned. Simple inspection, as well as mathematical analysis, shows that a given mass of matter rotating as a sphere will have a less moment of momentum than when it takes the form of an oblate spheroid, the time of rotation and other factors being equal. If a yielding sphere be rotated it takes the spheroidal shape because that is the form of equilibrium for the added rotational momentum, and is an expression of such addition. To give the Laplacian hypothesis the benefit of every doubt, the moment of momentum of the nebula is computed on the basis of a sphere. So also to favor the hypothesis, the nebula is made to reach merely *to* the orbit of the derived planet, not to extend beyond it as is usually and necessarily assumed. In computing the rotatory momentum of the whole nebular mass just before Neptune was separated, it is assumed that it reached only to Neptune's orbit, whereas the nebular border must probably have extended some 500 million miles beyond.

As this question of the distribution of the matter from which the planets were formed under the Laplacian hypothesis has other applications, it may be remarked here that in the formation of a planet from a ring of dispersed matter the planet must assume such a point within the ring as to preserve the moment of momentum of the mass. In a symmetrical ring this point is somewhere near the center of the cross section. Though subject to some qualifications from the greater circumference of the outer part and the possibly greater density of the inner part

and other contingencies, it will be sufficiently accurate for the purposes of this discussion to assume that the planets were formed in the centers of their respective rings, and that the space appropriate to each planet reached half way to the neighboring planets.

The more important consideration, however, in determining the rotatory momentum of the ancestral nebula is the distribution of its internal density. Our method has been to compute this on the basis of the recognized laws, using in particular the formula of Lane, and to compare results with the previous determinations of mathematicians and physicists.[1]

The distribution of density in such a nebulous sphere has been the subject of investigation by Lane, Ritter, G. W. Hill, George Darwin, Lord Kelvin, and others.[2] The results reached by all are in substantial agreement, though somewhat different analytical methods were followed. In obtaining the final numerical results used in this paper, the distribution of density found by Darwin was adopted. The method of computation is given in Dr. Moulton's paper in the *Astrophysical Journal.*

When the solar nebula extended to the orbit of Neptune and embraced the matter of the whole system and had a rotation

[1] The laborious work of making the computation was undertaken by Mr. C. F. Tolman, Jr., under the direction of Dr. Moulton, and preliminary results were obtained by him, but before these had been sufficiently verified he was called to a position whose immediate requirements prevented the completion of the desired verification. For this reason, and for the obvious advantage of resting the present argument as far as possible on the computations of an acknowledged authority, results reached by Darwin, which are applicable to a gaseous or meteoroidal nebula in convective equilibrium, have been adopted.

[2] LANE: On the Theoretical Temperature of the Sun under the Hypothesis of a Gaseous Mass Maintaining its Volume by its Internal Heat, and Depending on the Laws of Gases as Known to Terrestrial Experiments, Am. Jour. Sci., Vol. XLIX, pp. 56–74, 1870.

RITTER: Untersuchen über die Höhe der Atmosphäre und die Constitution gasförmiges Weltkoper, Wiedemann's Annalen (New Series), Vol. XVI, 1882, p. 166.

G. W. HILL: Annals of Mathematics, Vol. IV, 1888.

DARWIN: On the Mechanical Condition of a Swarm of Meteorites, and on the Theories of Cosmogony, Trans. Phil. Soc., 1888.

KELVIN: On the Origin and Total Amount of the Sun's Heat, Popular Lectures and Addresses, 1891. Constitution of Matter, pp. 370–429.

equal to the angular velocity of Neptune, its computed moment of momentum was 4848.055, while the present moment of momentum is 22.7666. The unit is an arbitrary one arising from the selection of convenient initial units. In this paper, Moulton's unit is converted into Darwin's unit, for convenience of comparison. It appears, therefore, that notwithstanding the concessions to the Laplacian hypothesis by which the present moment of momentum was made too large, and the nebular moment of momentum too small, the latter is still 213 times larger than the former. The dynamical law that demands constancy of moment of momentum is not even remotely fulfilled. A more rigorous computation, following the probabilities of the case without regard to its bearings on the Laplacian hypothesis, would increase the discrepancy.

Individual discrepancies.—Not only does the law fail of realization when the present system taken as a whole is compared with the ancestral nebula, but also in a comparison between the successive nebular stages and the corresponding parts of the present system. For example, the computed rotatory momentum when the nebula extended to Jupiter's orbit, and included the Jovian mass, was 1996.420, while the moment of momentum of the present system, minus the moment of momentum of Neptune, Uranus, and Saturn, is 14.1816. The discrepancy here is more than 140 to 1.

When the nebula extended to the earth's orbit, and included the terrestial mass, its moment of momentum was 857.330. The moment of momentum of the Earth, Venus, Mercury, and the sun, by hypothesis formed from this nebula, is only .71008. In this case the excessive estimate of the sun's moment of momentum, due to the assumption of homogeneity, introduces a disproportionately large error, and yet the discrepancy is 1208 to 1. Computing the sun's moment of momentum on the basis of Laplace's law of destiny, the discrepancy is 1801 to 1.

When the nebula extended to Mercury's orbit, and included this planet's mass, its moment of momentum was 512.290, while the moment of momentum of Mercury and the sun (excessively

estimated) is 0.67979, making the discrepancy 754 to 1. On the more probable basis of Laplacian solar density the difference is 1127 to 1.

From these data it appears that there is not only a fundamental and pervasive discrepancy between the computed nebular momentum and the actual present momentum, but there is also a strange irregularity in the discrepancies themselves. A fundamental error in the analytical work, or in the assumptions on which it is based, should give a systematic error, or at least a graded series of errors. But the discrepancy shown is not systematic or even graded. Not only are the discrepancies enormously large in themselves, but their irregularities are also large. This will appear better by bringing them together into a table.

Nebular M. of M.	Present M. of M.	Ratios.
Neptunian stage, 4848.055	22.76661	213 to 1
Jovian " 1996.420	14.18161	141 to 1
Terrestial " 857.330	0.71008	1208 to 1
Mercurial " 512.290	0.67979	754 to 1

2. *Can these discrepancies be due to a radical error in the law of density?*—It is certain that Boyle's law is not rigorously applicable to gases under all conditions, and it is pertinent to inquire whether any deviation from it can account for the discrepancies which the foregoing computations reveal. The researches of Amagat[1] and others have shown the nature of the deviations within the limits of experimental tests and Van der Waals' law furnishes a basis for the theoretical extension of these results to other conditions.

Near the temperatures of liquefaction the density increases faster than the law requires. Obviously the exterior of the nebula would be effected by lower temperature than its interior and would be most influenced by this variation so far as dependent on low temperatures. As the peripheral portion carries the largest part of the rotatory momentum any increased density there through failure of Boyle's law would increase the discrepancy.

[1] WÜLLNER: Experimental Physik. Tables. Vol. I, p. 542.

In the interior of the nebula the temperatures were probably far above the critical temperatures of all known substances, and this renders it improbable that central liquefaction prevailed during the nebular stages; indeed the very dispersion of the matter into so vast a volume as the Laplacian hypothesis postulates may perhaps be taken as an implicit assertion of the dominance of the gaseous laws throughout the mass. This is certainly the view of its ablest exponents. Lord Kelvin speaking of a globular gaseous nebula (selected to represent the primitive nebula), having the mass of the solar system and a radius forty times the radius of the earth's orbit, says: "The density in its central regions, sensibly uniform throughout several million kilometers, is one twenty-thousand millionth of that of water; or one twenty-five millionth of that of air."[1] Similar determinations may be found in the more elaborate computations of Darwin for varying dimensions of the nebula.[2] We are therefore apparently not dealing with densities, even in the central parts, greater than those covered by experimental evidence.

Besides, the present distribution of matter in the solar system offers an independent argument against any great central liquefaction, until after the earth was separated at least, for, by hypothesis, the earth was formed from the extreme equatorial periphery of the nebula, but the larger part of its material is of the most refractory kinds known and would pass into the liquid and solid states early in the history of condensation. There seems little ground therefore for assuming any effective condensation of the central matter of the nebula during at least the early stages of planetary evolution.

On the other hand, experimental evidence and theoretical deductions alike indicate that under very high pressures, where the temperature is also above the critical point, the density fails to increase as fast as the pressure. As these are the assigned conditions of the central part of the nebula, any failure of the law in this direction would increase the discrepancy.

[1] Popular Lectures and Addresses, I. Constitution of Matter, p. 419.

[2] On the Mechanical Conditions of Swarms of Meteorites, and on Theories of Cosmogony, Phil. Trans. Roy. Soc., 1888.

It does not appear therefore that there are good grounds for assuming a failure of the recognized law of density in such a direction as to relieve the great discrepancy shown by the computations. In any case there is the gravest reason to doubt whether it could reach a value represented by a multiplier ranging from 140 to 1200, not to say 1800.

But even if an arbitrary attempt were made to reduce the computed moments of momenta to consistency with those of the existing system, it is not apparent how it could be attended with success and preserve self consistency. The discrepancies are:

For the Neptunian nebula - - - -	213 to 1
For the Jovian " - - - -	141 to 1
For the Terrestial " - - - - -	1208 to 1
(or on the more probable basis) - -	1801 to 1
For the Mercurial nebula - - - -	754 to 1
(or on the more probable basis) - -	1127 to 1

Now any deviation from the recognized law must be supposed to be consistent for analogous conditions. If therefore we assume such a modification as to bring the moment of momentum of the Neptunian nebula into equality with the present moment of momentum, we must assume that a similar modification held good for all the subsequent stages, either in the same proportion or in some systematically increasing or decreasing proportion. But the ratios succeed each other in a very arbitrary way, and the Neptunian divisor will not bring the others into accord, nor will any obvious series of divisors built systematically upon it. Were the computation extended to the other nebulæ, additional irreducible irregularities would doubtless appear.

3. *The ratio of masses to momenta.*—In the symmetrical evolution of a spheroidal nebula by secular cooling, as postulated in the Laplacian hypothesis, it is reasonable, if not necessary, to suppose there would be some systematic and rational relationship between the masses separated from time to time and the moments of momenta of these masses, for the separation was due to a common progressive cause, the acceleration of rotation. The hypothesis may therefore be tested along these lines. In

the test here applied the question of nebular density does not enter, and certain assumptions that might be made to meet the previous discrepancies are here checked.

Just previous to the hypothetical separation of the Jovian ring from the solar nebula the moment of momentum of the latter, reckoned from the present momenta of its derivatives, was 14.1816, if the sun be regarded as homogeneous, or 13.947, if the sun's density followed Laplace's law which is probably much nearer the truth. Of this, Jupiter now has 13.469. Neglecting for the present subsequent transfers of momentum, it follows that when the Jovian ring separated it carried away 13.469 / 14.182 or about 95 per cent. (94.97 per cent.) of the total moment of momentum of the nebula (or 96.57 per cent. on the more probable basis). Now the mass of Jupiter's ring was 1 / 1049 of the parent nebula, or less than one tenth of 1 per cent. It thus appears that the unqualified Laplacian hypothesis involves the implicit assertion that in the formation of the Jovian ring less than one thousandth of the mass carried away 95 per cent. of the moment of momentum. Is this possible in a spheroid of gaseous or quasi-gaseous material in convective equilibrium? One nineteen-thousandth more of the mass thrown off with an equal proportion of rotational momentum would have exhausted the supply. Apparently the minor planets had a narrow escape from not being at all.

Similar but not uniform disparities appear in a comparison of the masses and momenta of the other planetary rings with their parent nebulæ. In such a comparison also the great disparities in the planetary masses become conspicuous.

The mass of the Neptunian ring was about five thousandths of 1 per cent. of its nebula and by hypothesis it carried away about 8 per cent. of the moment of momentum of the nebula.

The mass of the Uranian ring was four and a half thousandths of 1 per cent. of its nebula. It hypothetically carried away 6 per cent. of the nebular moment of momentum.

The mass of the Saturnian ring was less than a third of a hundredth of 1 per cent. of its nebula and yet it carried away 27 per cent. of the nebular moment of momentum.

The mass of the Martian ring was three hundred-thousandths of 1 per cent. of its nebula, and yet it took away 0.35 per cent. of the moment of momentum of the nebula.

The mass of the Terrestrial ring was less than a third of a thousandth of 1 per cent. of its nebula, and it carried away 2.4 per cent. of the nebular moment of momentum.

The mass of Venus' ring was about one fourth of a thousandth of 1 per cent. of its nebula, and it carried off 1.89 per cent. of the nebular moment of momentum.

The mass of the Mercurial ring was only about one fifth of a ten-thousandth of 1 per cent. of its nebula, and it hypothetically carried off 0.12 per cent. of the nebular moment of momentum.

Not only are these ratios very extraordinary in themselves, but their relations to each other seem scarcely less remarkable. This will appear more apparent when they are gathered into a table and referred to a common unit. This unit is one one-hundred-thousandth of 1 per cent of the individual nebular mass. It will be seen that on this *proportional* basis, the moments of momenta range through a gamut of more than ten points, the proportion of Mars being more than ten times that of its neighbor Jupiter.

Ring	Percentage of mass of its nebula	Percentage of M. of M.	Percentage of M. of M. reduced to basis of .00001% of nebular mass.
Neptunian	0.00507	7.93	.0156
Uranian	0.00454	6.31	.0139
Saturnian	0.02852	27.78	.0098
Jovian	0.09530	94.97	.00996
Martian	0.0000323	0.36	.1099
Terrestrial	0.0003160	2.42	.0766
Venus	0.0002495	1.89	.0755
Mercurial	0.0000205	0.12	.0566

There seems to be no systematic variation in these. It is furthermore remarkable that, high as is the ratio of Jupiter's moment of momentum to the parent nebula, it is proportionately surpassed in most other cases.

4. *Can these high ratios of the moments of momenta of the planets to the residual nebulæ be attributed to transfer of moment of momentum*

from the sun by tidal friction?—Darwin has made familiar the principle of the transfer of the moment of momentum of a rotating body to its satellite by his classic investigation of the evolution of the earth-moon system. Applying this principle to the solar system, is it possible to explain the low rotatory momentum of the sun and the high moments of momenta of the planets by a transfer of momentum from the former to the latter?

The most obvious and tangible effect of solar tidal friction on the planets is to destroy their rotations. The patent fact that most of them still retain high speeds of rotation is a physical expression of the limitations of past tidal action.

Darwin has computed the rotational momenta of all the planets that afford the requisite data and also the revolutionary momenta of their satellites.[1] Making a generous allowance for the unknown and uncertain factors and counting in unnecessarily the orbital momenta of the satellites, the whole internal momentum of the planetary systems falls short of a thousandth part of the sun's rotational momentum computed on the minimum basis. This means that to have reduced the sun's rotational momentum from twice the present amount to the existing status, and to have transferred this to the planets, more than a thousand times the total rotatory momentum of all the planets must have been destroyed. But this would be only a slight step toward the adjustment contemplated.

To realize what might be necessary, if the foregoing nebular computations are well founded, let the matter of the solar system be converted into a gaseous nebula in hydrodynamic equilibrium extending beyond the orbit of Neptune; let this nebula be given the moment of momentum of the present solar system, and then let it contract by cooling, with the development of accelerated rotation, as postulated in the Laplacian hypothesis. An inspection of the foregoing data will show that the centrifugal force would not become equal to the centripetal force until the nebula had shrunk far within the orbit of Mercury. The

[1] On the Tidal Friction, etc., pp. 519–523.

tidal problem then becomes the dispersal of the planets from this central position to their present places.

Concerning the competency of the solar tides to alter the orbits of the planets (and hence their moments of momenta), Darwin says:[1] "It may be shown that the reaction of the tides raised in the sun by the planets must have had a very small influence in changing the dimensions of the planetary orbits around the sun. From a consideration of numerical data with regard to the solar system and the planetary subsystems, it appears improbable that the planetary orbits have been sensibly enlarged by tidal friction since the origin of the several planets." Again, he says:[2] "If the whole of the momentum of Jupiter and his satellites were destroyed by solar tidal friction, the mean distance of Jupiter from the sun would only be increased by one twenty-five hundredth part. The effect of the destruction of the internal momentum of any of the other planets would be very much less." And again:[3] "The present investigation shows, in confirmation of preceding ones, that at this origin of the moon the earth had a period of revolution about the sun shorter than at the present by perhaps only a minute or two, and it also shows that since the terrestrial planet itself first had a separate existence the length of the year can have increased but very little, almost certainly by not so much as an hour, and probably by not more than five minutes."

Aside from the quantitative difficulties there are formidable qualitative ones growing out of the proportional distances of the planets and the enormous lapses of time involved in a tidal retrogression of the planets through the postulated distances.

Conclusions.—The general result of the inquiry is to show, if we have not somewhere fallen into error, various relationships of mass and momentum which are seemingly altogether incompatible with an evolution of the solar system from a gaseous spheroid controlled by the laws of hydrodynamic equilibrium

[1] Encyclopedia Brittanica, Article "Tides," p. 380.

[2] On the Tidal Friction, etc., p. 524.

[3] Loc. cit., p. 533.

and developing by secular cooling. The argument is equally cogent against an evolution from a meteoroidal spheroid controlled by the laws of convective equilibrium, such, for example, as that made the subject of investigation by Darwin in his memoir: "On the Mechanical Conditions of a Swarm of Meteorites and on Theories of Cosmogony."

The results point to an unsymmetrical distribution of matter and of momentum. It should go without saying that we assume a nebular origin in the broad sense of the term, but the inquiry seems to show that the original form of the nebula and the mode of its development are to be sought on new lines. The foregoing data seem to constitute criteria of a rather rigorous nature to which a working hypothesis must conform. They are thereby aids in the construction of a tenable hypothesis. They seem to require the assignment of some mode of origin by which the peripheral portion of the system acquired all but a trivial part of the moment of momentum, while it possessed but a trivial part of the mass. The first suggestion of these conclusions was the possible formation of the system by the collision of a small nebula upon the outer portion of a large one, the smaller one having necessarily a high ratio of momentum to mass, while the larger one may have had little or no rotatory momentum, or even an adverse rotation. The low degrees of ellipticity of the present orbits seem to present grave difficulties in the framing of a consistent hypothesis of origin along this line, but these may not prove insuperable.

The results also naturally turn thought anew toward existing nebula for an exemplification of the evolution of the solar system. It is not a little significant that of the thousands of nebula now known no one, I believe, closely represents the annular process; certainly none represents the secondary annulation coincident with the primary. To bring the current hypothesis into consistency with observed nebular states, it seems necessary to assign it to so late a stage of concentration and to such small dimensions as to be beyond observation—at most, a hypothetical resort.

Following a purely naturalistic and inductive method, it would seem that the spiral nebulæ, whose abundance is attested by the recent notable success of Professor Keeler in photographing numerous small ones, offer the greatest inherent presumption of being the ancestral form. While present knowledge of their dynamics is almost inappreciable, the suggestions of their forms and the distribution of their matter do not seem necessarily incompatible with the criteria deduced in this inquiry.

Both these suggestions are obviously very immature, and have their sole justification in a natural reluctance to offer destructive results only—a reluctance intensified by an acute consciousness that the hypothesis against which they are directed is perhaps the most beautiful and fascinating ever offered to the scientific public.

T. C. CHAMBERLIN.

EDITORIAL

For more than thirty years Mr. W. F. E. Gurley, of Danville, Illinois, formerly the official geologist of this state, has been one of the most systematic collectors of Paleozoic fossils in the Mississippi valley. Not only has he gathered together what is probably the best existing collection of Paleozoic fossils of the interior states, but he has secured a large amount of valuable material from other portions of this country and from Europe. The collection has furnished much material for study to such paleontologists as C. A. White, E. D. Cope, S. H. Scudder, J. S. Newberry, Leo Lesquereaux, and Charles Wachsmüth, and many types of the species described by these men are included in it. More recently Mr. Gurley himself, associated with the late S. A. Miller, of Cincinnati, has described many new species from the collection. Aside from these types Mr. Gurley has been fortunate in securing many other types of species described by Owen and Shumard, Hall, Wetherby, and Miller.

In addition to the types in the collection, which are about 600 in number, some of its most noticeable features are the following: an exceptional series of Devonian fossils from the falls of the Ohio, including crinoids, corals, brachiopods, and trilobites; a fine series of Kinderhook crinoids from Le Grand, Iowa; an admirable series of Coal Measure crinoids from Kansas City, Missouri; a large collection of fish remains from the limestones of the Mississippi valley; an almost exclusive collection of the vertebrate remains from the Permian bone bed near Danville, Illinois, including all the types of the species from this locality described by Professor E. D. Cope; and a fine series of blastoids and cystoids. Among the foreign material a choice series of Solenhofen slate fossils and an excellent series of Carboniferous crinoids from Moscow, are worthy of special mention. These features serve to show something of the contents of the

collection, but they constitute only a small portion of the whole. The entire collection is estimated to contain 15,000 species and several hundred thousand specimens.

Through the generosity of Mr. Gurley himself, this collection has recently become the property of the University of Chicago. It will be installed in Walker Museum as rapidly as possible and will constitute the nucleus of still further growth. It will be the policy of the University to make this collection, and the future additions to it, not merely an exhibition of rare and choice fossils, but a basis of research which will be open to competent students under approved conditions. It will, beyond question, prove to be eminently serviceable in promoting appropriate lines of investigation and will thereby constitute a notable contribution to the progress of historical geology.

STUART WELLER.

Reviews

The Diuturnal Theory of the Earth; Or, Nature's System of Constructing a Stratified Physical World. By WILLIAM ANDREWS. Published by Myra Andrews and Ernest G. Stevens. New York, 1899. 8vo, pp. 551.

The consideration that might naturally be awakened by the evidences of great labor under manifest limitations embodied in this posthumous book is well nigh forstalled by the bad taste and absurd presumption of the preface by Mr. Stevens in which Mr. Andrews is styled "the greatest scientist America has produced" who "left comparatively little to be accomplished," and so forth.

"The Diuturnal Theory of the Earth" consists essentially of the assumption that "the north terrestrial polar point is taken within 30° to the south siderial polar point, and returned to within 60° of the point under the north star, from whence it started," and that the essential features of geological history are due to this. This polar movement is assumed to have taken the form of a spiral migration involving "six polar transitions" across the eastern and western hemispheres. There is no serious attempt to show that such a movement was a fact either by inductive evidence or deductive theory. The author's method seems to have been the pre-scientific one of developing a conception essentially *ex nihilo* and of interpreting the phenomena by means of it. The book is interesting as an exhibition of great labor enthusiastically devoted to the broad themes of geology under limitations that precluded either the mastery of the facts needed for induction or the dynamic principles necessary for deduction. If the filial regard which has given it to the world a dozen years after the author's death had been content to rest it on the modest basis of the thoughtful efforts of a studious man working under conditions that precluded success, it would have been wiser than to put it forth with the pretentious assumption of having "made the patchwork of geology into a complete science."

T. C. C.

Memoirs of the Geological Survey of the United Kingdom. The Silurian Rocks of Britain. Vol. I, Scotland, 1899. By B. N. PEACH, JOHN HORNE, and J. J. H. TEALL.

This publication, which comprises the first volume of a proposed monograph on the Silurian rocks of Great Britain and Ireland, treats of the Silurian formations of Scotland in a praiseworthy degree of completeness. It is a work destined to maintain the high standard of excellence attained by the British Survey Reports.

The opening chapter is devoted to the physical features of the Silurian region. The region in general comprises the Southern Uplands which, lying between the Central Lowlands on the north and the Cheviot Hills and Solway Firth on the south, stretch from the North Sea to the Irish Channel. The topography of the region varies from the uniformly smooth or undulating types in the central and eastern parts to the rugged craggy type of the southwestern part. The Uplands vary in height from one to two thousand feet. The northern border is traversed by an extensive fault which lets down the Devonian and Carboniferous rocks of the north to form the surface of the Central Lowlands.

The succeeding chapter is devoted to the history of previous researches among the rocks of this district. These researches cover a period of more than a century, and have engaged the attention of many of Britain's foremost geologists of the past and present. Beginning with Hutton among others are the names of Hall, Fairplay, Nicol, Harkness, Murchison, Sedgwick, Ramsay, A. Geikie, J. Geikie, and Lapworth, besides the names of the authors, Peach, Horne, and Teall. To Lapworth is given the credit of establishing by paleontological and stratigraphical achievements the true order of succession of the Silurian strata. His studies of the sequence of the Silurian graptolite faunas made possible the correction of erroneous estimates of the thickness of the beds and enabled the structure of the region to be worked out in the most complicated areas.

The stratigraphy and the tectonic arrangement of the rocks are set forth in the third chapter of the volume. The Lower Silurian series is divided into the Arenig, the Llandeilo, and the Carodoc formations. The Arenig strata consist of cherts, mudstones, shales, and volcanic tuffs interbedded in places with tuffs, lavas, and agglomerates, associated with intrusive masses comprising serpentine, olivine, enstatite

rock, and gabbros. Many of the volcanic eruptions took place under submarine conditions. There were also periods of quiescence, during which fine sands and mud containing fossils were deposited.

A subsidence of the sea floor ushered in the next period, the Llandeilo. The rocks of this formation are radiolarian cherts and mudstones which were deposited in clearer waters than the rocks of the Arenig. The rocks of the Carodoc are shales, conglomerates, and limestones, implying variable conditions of deposition.

The Upper Silurian, it is said, is separated from the Lower Silurian by both physical and paleontological changes. But there appears to be no great paleontological break such as characterizes the separation of the Ordovician from the Silurian on the interior of the American continent. The transition from the Lower Silurian to the Upper Silurian types is a gradual one. This province may constitute one of harbors of refuge spoken of by Professor Chamberlin in his discussion of the source of provincial faunas. It would correspond, then. on the American continent, to the embayment at the mouth of the St. Lawrence. The following table will serve to compare the distribution of the Brachiopods common to the two countries, Scotland and America:

	Scotland		America	
	Lower Silurian	Upper Silurian	Ordovician	Silurian
Atrypa reticularis	x	x	..	x
Atrypa marginalis	x	..	..	x
Cyrtia exporrecta	..	x	..	x
Leptaena rhomboidalis	x	x	x	x
Plectambonites transversalis	x	x	..	x
Platystrophia biforata	x	x	x	x
Rafesinesquina alternata	x	..	x	..
Bilobites bilobus	x	x	..	x
Dalmanella elegantula	x	x	..	x
Dalmanella testudinaria	x	..	x	..
Orthis tricenaria	x	..	x	..
Pentamerus oblongus	..	x	..	x
Uncinulus stricklandi	x	..	..	x
Spirifer crispus	x	x	..	x
Spirifer radiatus	..	x	..	x
Rafesinesquina deltoidea	x	x	x	..
Rafesinesquina imbrex	x	..	x	..
Total of species	14	11	7	12

This table shows that of the fourteen species occurring in the Lower Silurian of Scotland but one half that number are represented in the American Ordovician, the other seven species appearing in the American Silurian. As most of these species occur in the last member of the Lower Silurian, the Carodoc, it is probable that this formation forms the transition zone between the Ordovician, as we know it, and the Silurian.

The Upper Silurian series is divided into the Llandovery, the Tarannon, the Wenlock, the Ludlow, and the Downtonian. These formations consist of mudstones, limestones, grits, graywackes, and conglomerates. The Downtonian which hitherto has not been recognized as a part of the Silurian is probably the equivalent of the Waterlime formation of our own country. It contains a fauna consisting of Ostracoids, Eurypterids, and fishes similar to the fauna of the Waterlime formation. This formation immediately underlies the Old Red Sandstone.

The economic products of the Silurian formations are lead, iron, copper, antimony, manganese, zinc, mispickel, silver, and gold, besides building materials, road-metal, and hone-stones.

Other chapters in the book are devoted to contact-metamorphism, and to the granites and associated igneous rocks.

W. N. Logan.

Genesis of Worlds. By J. H. Hobart Bennett. Springfield, Ill.: H. W. Rokker, printer, 1900. Pp. 345.

This work does not need serious review from the point of view of science. It is the product of a mind deeply interested in the problems of cosmogony and apparently ready to accept the demonstrations of science, but yet still under the dominance of the traditional anthrophic mode of thought. It betrays throughout a serious lack of firm grounding in the elements of the sciences involved in the subjects under discussion, a grounding absolutely necessary to their successful treatment. The mode and style of the book may be illustrated by the following quotation from page 3:

> Inquiring minds have a propensity for tracing things to a first cause, and would ask from whence came the great nebula. It could not have sprung into existence already formed. It had an origin which is worthy of a most careful investigation, for it is one of a class that is represented by thousands

of similar bodies in the heavens. May not a conjecture of its antecedents be properly presented here? It is that when the great Creator would form a new system of worlds, having allotted a district of suitable form and dimensions for the purpose, he changes the primordial matter in it from a gaseous condition, in which it had been under the law of repulsion, into cosmical dust, by which slight change it became subject to the law of gravitation.

And the following from pages 72 and 73:

Any matter erupted from the sun can return to it again, as it does constantly from its prominences. But there seems to be a repulsion between all comets and the sun. They are attracted toward it, but never to it. After one revolution the reason may be given that they have established orbits. But that reason does not apply to the first approach. Any other bodies gravitating toward the sun from the depths of space would fall directly upon it. But cometary matter seems to be governed by an unknown law, a law of gravitation limited. There is attraction at a great distance, but repulsion on near approach. Is it not evident from the following quotation? "The great comet of 1843 passed within three or four minutes of the surface of the sun, and therefore directly through the midst of the corona. At the time of nearest approach, its velocity was three hundred and fifty miles a second, and it went with nearly this velocity through at least three hundred thousand miles of corona, coming out without having suffered any visible damage or retardation" (NEWCOMB'S *Popular Astronomy*, p. 251).

Was not that a clear case of mutual shrinkage or gathering of skirts as two persons would gather their delicate robes to avoid contact when passing too near each other?

Occasionally the style falls off to this:

This hypothesis presents, in a greater degree than any explanation heretofore offered, the elements of possibilities in the tissue of forces and their observed effects. Indeed those effects demand a reasonable exposition of producing causes.

The author attempts to solve some of the fundamental problems of geology by giving enormous magnitude to the rendering and triturating effects of the descent of the waters of the supposed primitive vaporous atmosphere upon the assumed hot earth. Respecting this he says:

The inquiry must arise in every thoughtful mind, to what depth will the breaking of the rocky crust extend? What can arrest the destructive action of the water? Will the weight of the débris affect it at the depth of one mile, or two miles, or three miles? No, nothing can resist the explosive power of steam. It opens the way and keeps it open for the

downward progress of water. Nothing can arrest the destruction of the rocky crust so long as there is rock to be broken. The entire solid crust of the earth must be transformed, must be rent into fragments. The water reaches the molten mass below and can go no farther. . . . .

Again the phenomenal changes and the condition of the earth's crust embarrass our powers of description, and even conception. The water having reached the molten mass below the fragmental crust, could go no farther. It had reduced the temperature of the upper surface more nearly to that of boiling water, while that of the molten mass below the broken crust was nearly forty-four hundred degrees higher. The entire mass, thirteen miles in depth of débris and water, is kept in violent motion by the resistless power of steam over the entire surface of the globe.

On this "true basis," in negligence of the most obvious limitations of a well-recognized action, the author builds theories of elevation, vulcanism and stratification, and assumes that he has solved some of the great problems of geology.

Those who are not well versed in what is established will read the book at much risk of mixing needless error with truth, while those who are so versed will probably find it interesting chiefly as a psychological study.

The book is pervaded by an ostentatious piety of the type prevalent in the last century, which is liable to produce a moral effect quite opposite to that intended. True reverence is best displayed by refraining from presuming to know the mind and purpose of the Infinite and by scrupulously dissociating one's imperfect notions from all connection with Omniscience. T. C. C.

Text-Book of Paleontology, by KARL A. VON ZITTEL, translated and edited by CHARLES R. EASTMAN. Vol. I, Part II, pp. 353–706, with 883 wood-cuts. Macmillan & Co., 1899.

After an interval of more than three years since the appearance of Part I, the invertebrate portion of Zittel's Paleontology is at last brought to a conclusion. The plan and scope of this work was discussed at length in a review of Part I, which appeared in this JOURNAL for October 1896; hence it is only necessary to repeat here that the English edition is a composite production, much of Zittel's text being discarded and replaced by original contributions from a dozen different authors, whose names are given on the title-page.

The Grundzüge der Paläontologie, which forms the basis of the present work, is an essentially modern, useful, and very compact treatise. It compasses within 900 odd pages the whole field of paleozoölogy, rather more than one half of the space being devoted to invertebrates. The descriptions of genera are brief but to the point, the illustrations numerous, and the arrangement simple and well-balanced. These are salutary features for any elementary text-book to possess, and the writings of von Zittel have set a high standard for other authors to emulate.

As compared with the original, we note in the first place that the English edition devotes about 200 more pages to the invertebrates, and is enriched by nearly 100 new figures. Over 4600 generic names are enumerated in the index, being about 1200 in excess of the invertebrates treated in the German edition. The amount of enlargement is therefore considerable, and the new genera introduced are mostly those which are of importance in American and British strata.

All the generic diagnoses are of necessity very brief, and large numbers of names are cited without definition, simply as an index to their family position, or degree of family differentiation. Typical or otherwise interesting forms are treated more at length, and in some instances type-species are listed; but the definitions of families and larger groups are as a rule succinctly yet carefully stated. The book serves as an excellent guide for orientation over the different groups and as a catalogue of the more important genera, but does not permit of the identification of less important genera without the aid of special literature. In compensation for this, copious bibliographies are inserted under nearly every caption, those for the Cephalopods and Trilobites being especially complete and all of them brought strictly up to date.

Many radical changes are to be observed in the classification, the responsibility for which, we are told in the preface, lies with the revisers of the different sections. The rearrangement of Pelecypod families and genera by Dr. W. H. Dall is in accordance with the latest conceptions of this eminent conchological authority. Great emphasis is laid by Dr. Dall on the distinctness of family groups, and many well-known genera are taken by him to represent types of new families, or subfamilies. Nor is Dr. Dall alone in this tendency toward elevation of families out of generic characters; it seems to be becoming more and more the fashion in all branches of systematic biology, and probably

the most remarkable illustration of all is to be seen in Professor Hyatt's new classification of Cephalopods. The chapters on Nautiloids and Ammonites, occupying 75 pages, have been entirely rewritten by Professor Hyatt, and represent in epitome a life work expended on the study of these groups. The system followed was proposed in outline at the Boston meeting of the American Association, two years ago. Its essential feature consists in the elevation of the three leading "genera" of von Buch, *Goniatites*, *Ceratites*, and *Ammonites*, together with the Clymenoids of Gümbel, into as many different suborders, and in addition to these, several entirely new ones are recognized among the Goniatites and Ammonites. A large number of genera are made the types of independent families, and the prevailing feature throughout is the comparison of young stages of specialized forms with the adult of primitive types. As the entire life history of Ammonites and other groups are recorded in the progressive changes taking place in the shell, this class of organisms is especially well suited for comparative investigations based on the principle of accellerated development.

The chapter on Trilobites is from the pen of Professor C. E. Beecher, our leading authority on this group. The treatment is much fuller than in the original, and a considerable number of new figures are added. As in the Ammonites it is of prime importance to compare the ontogenetic stages, and this furnishes the key to the new classification of Beecher, since adopted by Cowper, Reed, Bernard, and others, although opposed by Pompeckj. Trilobites are here accorded the rank of a separate subclass, all other crustacean forms being set off against them under the title of Eucrustacea. The latter have been revised for the present work by Professors J. M. Clarke and J. S. Kingsley, with the exception of the Ostracoda, which are accredited to Mr. E. O. Ulrich. A noteworthy point consists in the removal from Crustacea of the Merostomata, including Limulus, the Eurypterids, etc., and associating them with the Arachnids under the head of the *Acerata*, of Kingsley. This step, it is believed, will eventually be acquiesced in by most specialists on these groups. Altogether, the chapters on Arthropods show evidence of most careful revision, and are well-balanced as regards space.

We come lastly to the chapters on Arachnids, Myriopods, and Insects, which have been revised and slighly enlarged by that indefatigable paleoentomologist, Professor S. H. Scudder. Save for being

simpler and briefer, the treatment is much the same as that followed in the *Handbook* of von Zittel, the chapters in question having been prepared for that work by the self-same author. Here also new figures are inserted, a very striking one being Brongniart's restoration of *Meganeura*, a dragon-fly having an expanse of 30 inches between tips of wings. The book concludes with a complete index of genera and subgenera.

The present edition of the von Zittel places in the hands of every English-speaking student a good elementary text-book that has long been needed. It is significant that in the "Eastman translation" so much American material has been introduced, and that so much revision has been done by American specialists.

Regarding the work as a whole we may repeat what was said of the first part, that educators in general owe to Dr. Eastman a deep debt of gratitude for providing our college and higher schools with a "translated, revised, and enlarged edition" of the best manual of paleontology that has ever been written. Professor von Zittel is to be congratulated, not only for the improvement presented by his new elementary text-book, but also, as shown by the results, for having entrusted the preparation of the translated edition to such excellent hands.

CHARLES R. KEYES.

The Gold Measures of Nova Scotia and Deep Mining. By E. R. FARIBAULT. Canadian *Mining Review*, March 1899, Pp. 11, with 6 plates.

E. R. Faribault, of the Canadian Geological survey, has lately announced the results of fifteen year's work on the gold measures of Nova Scotia. These results are of great interest, both from a scientific and economic standpoint.

The gold measures of Nova Scotia are confined to the metamorphic Lower Cambrian quartzites and slates, forming a belt along the Atlantic coast from 10 to 75 miles wide. Intruding these rocks are large masses of granite occupying nearly a third of the superfices of the province. These were intruded in Silurian time, after the folding of the strata and deposition of the gold-bearing quartz, and need not be considered. The originally horizontal quartzites and slates have been folded into a series of huge undulations roughly parallel with the seacoast. The amplitude of the folds varies considerably, but

the average is about three miles. A section of 35 miles across the gold measures gives eleven anticlines. These folds have been greatly flexed in a direction transverse to the closer folding, so that they form long domes. In the folding, the upper strata have slipped upward on the lower strata, these movements taking place largely along the soft slate layers between the hard quartzite layers. This has resulted in compression along the sides of the folds and the formation of openings along the crests.

Gold-bearing quartz has been deposited in the openings near the crests of the domes formed by the slipping of the layers. The veins thus deposited thin out rapidly along the limbs of the folds, but keep their size along the pitch for some distance, though finally pinching out. Where the folding has been close and the legs of the anticline form an angle of less than 45°, the large bodies of quartz on the anticline are called *saddle reefs*, the name given to such formations in Australia.

As yet no general operations have been carried on to any depth through the arch core of the folds in Nova Scotia, although at various places a number of veins have been found. However, from analogy with the Australian gold-bearing veins occurring in a similar manner, it is believed that the quartz veins in Nova Scotia will be found to recur many times in depth.

The laws governing the position and extent of the zones of quartz veins, as well as the laws governing the position and extent of the "pay streaks" within the veins, are given in detail.

This work of Mr. Faribault's will be of immediate practical advantage to mining men, some of whom have already testified to its accuracy and value. It is another instance, lately of frequent occurrence, of geological work done from a purely scientific standpoint having direct economic value.

From a scientific standpoint also, the results are of interest as illustrating a principle of ore deposition. In many districts, and particularly in the Lake Superior District, it has long been known that ore deposits were partial concentrates in pitching troughs by decending waters. Van Hise has lately enunciated the principle that the openings in arches or pitching folds are favorable places for the concentration of ore deposits by *upward moving waters*. The formation of the gold-bearing veins of Nova Scotia seems likely to have occurred in this way.

C. K. L.

Maryland Geological Survey, Vol. III, Baltimore. The Johns Hopkins Press, 1899.

This volume consists of the application of geology to the "permanent and economical improvement" of the roads of Maryland. It consists of 461 pages and 80 pages on "Laws of Maryland relating to highways." There are 35 plates, including 14 maps, and 38 figures.

The state geologist, Professor William Bullock Clark, contributes the Preface, Part I, Introduction, and Part II, "The Relations of Maryland Topography, Climate and Geology to Highway Construction." The author discusses the "dependence of the highways upon the surface configuration of the land," and their dependence upon the underlying formations; the effects produced upon the roads by temperature changes, precipitation and winds. He gives the areal distribution of the various geological formations of the state, accompanied by a map, and with a hint to roadmasters to make use of the information. Then follows a discussion of the road materials of the state and their relative values for road building.

Part III, "Highway Legislation in Maryland, and its Influence on the Economic Development of the State," is contributed by St. George Leakin Sioussat.

Part IV, "The Present Condition of Maryland Highways," and Part V, "Construction and Repair of Roads," are by Arthur Newhall Johnson.

The condition revealed in Part IV amply justifies the Survey in its undertaking to direct attention to the need and the methods of improvement. Yet Maryland has some excellent highways, and the average condition of its roads is perhaps as good as in most of the states. On the other hand Massachusetts and Connecticut are states which are noted for their good roads. In Part V Mr. Johnson gives practical instruction on grading, drainage, and surfacing which will be of great service in road-building,

The following Parts, VI, VII, VIII, are by Harry Fielding Reid. Part VI treats of the "Qualities of Good Road-Metals and the Method of Testing them." In this chapter Professor Reid deals with the following series of laboratory tests of materials, viz., microscopic test; abrasion test; crushing test; cementation test. The results of these tests upon various rocks are illustrated. Part VIII, relative to "The Advantages of Good Roads," is adapted to awaken an interest in road improvement.

If the people of Maryland shall become convinced that, in addition to incidental advantages, "a sum in the neighborhood of three million dollars would be annually saved by improving the important roads of the state," there will be no difficulty in getting appropriations for road building and repairs. The volume will exert a wide influence for the betterment of the roads of the country. As a piece of bookmaking it is exceptionally good. The type is clear, the illustrations are apt and well-made. The Survey is to be congratulated upon presenting in such excellent form a volume replete with valuable information and suggestion.

JAMES H. SMITH.

Maryland Weather Service, Vol. I, Baltimore. The Johns Hopkins Press, 1899.

The Maryland Weather Service is conducted under the auspices of the Johns Hopkins University, the Maryland Agricultural College and the U. S. Weather Bureau.

In Part I, Introduction, Professor William Bullock Clark gives a brief history of the State Weather Service and presents "lines of investigation pursued by the Service." These are topography, physiography, meteorology, hydrography, medical climatology, agricultural soils, forestry, crop conditions, flora, and fauna. He also enumerates the previous publications of the Service.

Part II consists of "A General Report on the Physiography of Maryland, by Cleveland Abbe, Jr. Professor Abbe discusses physiographic processes in general and takes up briefly each of the physiographic provinces of the state. A study of stream development of the Piedmont Plateau leads to the conclusion that [1] "The streams of the eastern division of the Piedmont Plateau have been superimposed from the formerly more extensive Coastal Plain cover."

Thus the explanation of McGee is confirmed by detailed field work—at least in the eastern part of the plateau. On page 132, Professor Abbe uses the phrase "Topographic Valences of the Rocks." The word "valence" in this connection is not defined, but immediately following the heading quoted the author speaks of the "different degrees of resistance which they [rocks] offer to weathering and erosion." These resistances appear to be what is meant by the term "valences." Since valence is used in a quite different, but definite,

[1] P. 216.

sense in chemistry; and since it has still another meaning in biology, we doubt the wisdom of giving the word a third technical meaning in geology. And if it means resistance to denudation the coining of a new term does not seem to be demanded.

Part III consists of a "Report on the Meteorology of Maryland," by Cleveland Abbe, F. J. Walz, and O. L. Fassig. Professor Abbe takes up Dynamic Meteorology and its Applications; Climatology and its Aims and Methods, and Apparatus and Methods. Among many suggestive topics we note with approval the emphasis put upon "Paleoclimatology"—a subject that is receiving increasing attention on the part of geologists. Professor Abbe strongly states the case when he says,[1] "Geology is primarily a study of the influence of the overlying atmosphere upon the earth beneath. It is, therefore, an essential part of the study to understand the climates and the changes in climate that have prevailed since the earth began its annual course around the sun and its diurnal revolution around its axis. The study of modern climates must be considered by the geologists as simply an introduction to the equally important study of ancient climates and the work done by them." Dr. Fassig presents "A Sketch of the Progress of Meteorology in Maryland and Delaware." Mr. Walz gives an "Outline of the Present Knowledge of Meteorology and Climatology of Maryland." The weather maps, showing types of weather in various places and seasons are well selected and are very instructive. There is a chart showing normal temperature and pressure for Maryland, including Delaware and the District of Columbia for each month of the year; also one each for spring, summer, autumn, winter and for the year. There are also many tables for reference.

The volume is a handsome one of 566 pages, 54 plates, some of which are colored, and 61 figures. All of the illustrations except Plate XXXV are pertinent to the subject discussed and add much to the value of the volume. Plate XXXV is a picture of the office of the Weather Bureau at Baltimore. It adds nothing of scientific value and would therefore better have been omitted. It seems ungenerous to mention so small a matter, for the volume is presented in an almost faultless form both as to subject-matter and as to mechanical execution.

JAMES H. SMITH.

[1] P. 304.

Principles and Conditions of the Movement of Ground Water. By FRANKLIN HIRAM KING, with a theoretical Investigation of the Motion of Ground Waters, by CHARLES SUMNER SLICHTER. Ext. Nineteenth Ann. Rep. U. S. Geol. Survey, Part II, 1899, pp. lxi + 384.

This important paper bears throughout evidences of the painstaking industry that marks all of Professor King's work. It deals first with general considerations relative to the amount of water stored in the ground in different kinds of rock. For the Dakota sandstone he assigns 15 to 38 feet of water for every 100 feet in thickness of the rock. The water in the Potsdam sandstone of Wisconsin and adjoining states he makes equivalent to an inland submerged sea having a mean depth of 50 to 190 feet of water for the area occupied. In regard to the superficial soils and sands, Professor King gives more detailed data, as this lies in his special field of investigation. A saturated sand carries from 20 to 22 per cent. of its dry weight of water, while the soils and clays range from these values all the way up to 40 and even 50 per cent. of their dry weights. "Since a cubic foot of dry sand weighs from 102 to 110 pounds, while soils, clays and gravels range between this and 79 pounds, we have a ready means of expressing quantitatively the water which is continually stored in this mantle of loose material when it lies below the plane of saturation." In a table of actual determinations where loamy clays and very fine sandy soils are involved, 2 feet of water in 5 feet of soil below the horizon of saturation are shown. When soil does not lie below the plane of saturation it usually contains 75 per cent. of the amount required for full saturation, except during dry times when a surface layer of one to five feet thick falls below this. Even where the plane of saturation lies below a large thickness of soil there is still a large storage capacity for water.

In rocks other than sandstones and soils the percentage is usually very much smaller. Its cumulative magnitude is indicated by the statement that so small an amount of water as 0.0023 of the weight for 5000 feet of the earth's crust is large enough to form a continuous sheet about the globe 30 feet deep. It is believed that water penetrates the crust to depths even exceeding 10,000 feet. Reckoned at 1 per cent., with a specific gravity of rock of 2.65, the amount contained would be a layer 265 feet thick. Of course the amount in the upper horizons is

relatively large and that in the lower very small. An estimate of this kind gives an impression large or small according to the point of view. Regarded by itself, it is large, but compared with the whole hydrosphere it is but a small factor and does not very appreciably add to the oceanic volume. It probably does not amount to so much as the probable error in the estimation of the volume of the ocean and other superficial waters. If the water of hydration be added to it, the statement may not improbably still hold true.

In the treatment of the general movements of the ground water three categories are recognized: (1) Gravitative, (2) thermal, and (3) capillary movements. The oscillations in the flow of springs and artesian wells are illustrated by autographic records and their relations to barometric changes demonstrated. Even the sudden barometric changes accompanying a shower are sometimes sharply recorded. Diurnal changes in temperature are shown to effect the rate of seepage. This is attributed chiefly to the indirect effect of the temperature through the expansion of the gases in the soil. Movements of ground water are ascribed to rock consolidation and crust deformation. Of the 25 to 50 per cent., by volume, of water inclosed in the sediments, when first laid down, a considerable part is forced out as the sediments settle into greater compactness, and finally pass into indurated rock. By an ingenious device on automatic flow from the base to the top of a cylinder of settling sediments was secured against a head of six inches. In the dynamic consolidation of rocks, a still larger per cent. of the inclosed water is forced out. The growth of grains and the filling of pore-spaces is a concurrent source of expulsion of water. Limestones as now taken from the quarries have, as a rule, a pore-space varying from less than 1 per cent. to 7 or 8 per cent. at most; so that the final formation of every 1000 feet of compact limestone means an expulsion of water from these beds during the process of growth and consolidation amounting to not less than one fourth, and possibly as much as one half, of the present volume of the rock.

For the capillary movements of ground water recourse must be had to the paper itself, as the tables cannot be briefly and adequately summarized.

The configuration of the ground water surface is illustrated by contour maps and the flow dependent on this configuration diagrammatically indicated. The changes in the configuration that result from precipitation are shown by tables and by diagrams.

Then follows an account of an elaborate series of investigations of the flow of water through soils, sands, rocks, and other porous media. These are much too extended to be reviewed in detail. They furnish data of prime importance to studies in irrigation, water supply, and various other inquiries that involve the size of grain, the pore-space, and the various elements of resistance to percolation. The industrial as well as the scientific value of these determinations, with which are collated those of others, is obvious.

The value of the experimental study of Professor King is greatly enhanced by the theoretical investigation of the motions of ground water by Professor Slichter. The treatment is mathematical and can be read only by those who are familiar with its elegant language. The excellent illustrations, however, translate some of the more vital parts into the vernacular. Those which relate to the interferences of flows into artesian and other wells are especially instructive.

T. C. C.

Les Lacs Francais. Par ANDRÉ DELEBECQUE. Ouvrage couronné par l'Academie des Sciences. 436 pp., 22 plates, and 153 figures in the text. Accompanied by an atlas of 10 maps. Paris: 1898.

This elaborate work is divided into ten chapters, and a brief outline is here given of the substance of each:

I. *Distribution.*—Most of the lakes of France are in the mountains, the Alps, the Juras, the Vosges, and the Pyrennees; but there are some in the central plateau, some along the coasts, and still others which do not admit of ready classification. The total number of lakes given is between 460 and 470, but many of them are so small that in our own country they would be called ponds.

II. *Depth.*—The second chapter has to do with the depth of the lakes, and the chartings of the soundings.

III. *Description.*—The third chapter is a description of the principal lakes, the description taking account of the depth, the area, the position, etc. Contour maps of the basins of more than forty lakes are given on the plates. Of lakes more than 25 meters deep, there are thirteen in the Alps, eleven in the Juras, two in the Vosges, eight in the central plateau, twelve in the Pyrennees, and one on the coast of the Mediterranean, forty-seven in all. Of lakes more than 1000

hectares (approximately four square miles) in area, there are in the Alps two, in the Juras one, along the Atlantic coast four, and along the Mediterranean coast two. Even of lakes more than 250 hectares in area (approximately one square mile) there are but thirteen. It will be seen therefore that most of the lakes are very small. The tables show that the depth of many of them is great in comparison with their area.

IV. *Topography*.—The fourth chapter deals with the character of the topography and relief of the lake bottoms. Few of the lakes have great depth. Lake Geneva has a maximum depth of $\frac{1}{237}$ of its length and $\frac{1}{54}$ of its width, but these ratios are exceeded by many of the smaller lakes. The deepest lakes in proportion to their area are in the Pyrennees. Here Lac Bleu has a depth of 120 meters with an area of but 47 hectares. In the lake bottoms are recognized (*a*) the marginal plains, partly wave cut and partly wave built; (*b*) the tallus slopes (a talus slope of 87° runs down to a depth of 42 meters in one case, and a slope of 63° to a depth of 100 meters in another), and (*c*) the bottom flats. In the large lakes the sensible flat (or flats) at the bottom is some considerable fraction of the total area. In Lake Geneva the bottom flat of an area one twelfth of the total area of the lake has a relief of less than five meters. These flat bottoms are naturally more distinct in the large lakes than in the small ones. Certain more or less accidental features are recognized in the topography of the lake bottoms. Here are classed deltas, submerged valleys, ravines, hills and islands and funnels. The latter are rare, and represent either places where springs enter the lake, or where sub-surface drainage escapes. Two or three remarkable instances are cited, especially in Lac d'Annecy.

V. *Nature of the bottoms*.—The nature of the bottom is the topic of the fifth chapter. The bottom consists in part of alluvium, and in part of the rock in which the basin occurs. The alluvial material is found to vary both microscopically and chemically with the nature of the rock of the basin. Numerous tables of results are given. The following conclusions are reached: (*a*) The material at the bottom of the lake varies with the rock. In limestone basins calcareous matter dominates, while in basins in siliceous rocks, quartz is most abundant. (*b*) The mean composition of the sediment in the lake is not the same as the mean composition of the rocks in the basin. For example, the sulphates are essentially absent in certain lakes whose

affluents flow over gypsum, or whose shores are partly of gypsum. On the other hand, sulphuric acid is found in small quantity in lakes where there is no gypsum adjacent. Again, calcium is abundant in basalt, but not in the sediment in lakes in basaltic regions. Alkalis are plentiful in granitic rock, but only sparingly present in the lakes in granitic basins. The alkalis and alkaline earths are carried off in solution, chiefly as carbonates, while the silica stays behind and is thus concentrated. (*c*) The composition of the sediment varies in different parts of the same lake.

Sediment is absent in the bottom of the lakes where the slope is too steep for it to rest, in general where the slope is over 45°, and where local conditions have prevented deposition, as where springs enter or where drainage flows out. Sediment is also absent where currents have been effective at the bottom.

VI. *Supply and loss.*—A chapter is devoted to the supply and loss of water, and to the variations in the levels of the lakes. An interesting section is given to the average length of time which water stays in lakes. This is determined from the volume of the lake, and the rate of outflow. Thus in Lake Geneva, it is found that the average stay of water in the lake is eleven years and seventy-three days; in lake d'Annecy three years and one hundred and thirteen days; in Lake Chaillexon five days. Many other calculations are given, all of which tend to show that the duration of the stay of water in lakes is extremely variable. Lakes with surface outlets are found to change their levels but slightly. Data on this point seem somewhat imperfect, but the maximum known fluctuation in the case of lakes having surface outlets is three meters. In lakes having sub-surface outlets, fluctuations of level are far greater. They appear also to be greater for small lakes than for large ones. Thus the level of Lake Chaillexon between August 19, 1892 and December 31, 1895, fluctuated sixteen meters.

VII. *Temperature.*—The tables of temperature given show that the water at the bottoms of the deep lakes varies very little, and that it is near the temperature of greatest density all the time. The tables show that in most lakes there is a well-defined zone which separates the warm (during most of the year) water above from the cold water below, the transition being usually rather abrupt. This zone of transition is rarely more than twenty meters below the surface, and sometimes not more than ten. The causes determining temperature are considered. Aside from (*a*) climate, the effect of which is obvious, (*b*) the average depth, (*c*)

the form and orientation of the lakes, and (*d*) the sources of supply, influence their temperature. The form and orientation of the lakes is of importance in connection with the winds. Lakes which are oriented so as to allow winds to exert their most important influence in the generation of currents, have their temperature equalized in the vertical sense, through the return currents. Circulation is thus shown to be of more importance than conduction in equalizing the temperature between top and bottom. The rôle of affluents in determining lake temperatures is very variable. It depends on the size of the lake, the average stay of the water in the lake, and the nature of the affluents themselves. Following Forel, the author emphasizes the paradoxical fact that the waters of the glacial Rhone raise the temperature of Lake Geneva, the temperature of the river being notably above that of the lower part of the lake at all times, while the large amount of sediment in the river water so increases its specific gravity as to cause it to descend much below the zone of lacustrine temperature corresponding to its own. Sub-surface affluents exert an important influence in their immediate surroundings, or, if the lake be very small, on the whole volume of water. The temperatures of these affluents being essentially constant, the temperature of the lake is differently affected by them in different seasons. Lakes are classified by the author, following Forel, on the thermal basis, as *tropical*, *temperate*, and *polar*. The tropical lakes are those whose surface waters do not reach 4° C.; the temperate lakes are those the surface waters of which are sometimes below and sometimes above 4°; while the polar lakes are those whose surface waters never rise above 4°. Of the first class the larger part of Lake Geneva, and certain salt lakes near the shore are the only representatives. To the second class most of the lakes of France belong, but there are a few representatives of the third class in the Pyrenees, and in certain other high altitudes.

Chapter VIII deals with the *transparency*, *color*, etc., of the lakes. The lakes are partly blue (few), partly green (the larger number), and partly yellow (a large number.) The color is found to be influenced by (*a*) the dissolved organic substances, such as humic and ulmic acids; (*b*) the presence of vegetable and animal organisms in the water; and (*c*) the inorganic sediment. The transparency is found to vary within a given lake with the season, and with the position of the station. It is greater in winter than in summer, and increases with increasing distance from the debouchures of streams. The water of the blue lakes is

most transparent, that of the green less, and that of the yellow least.

IX. *Matter dissolved in the water of the lakes.*—With the exception of the salt lakes, none of the lacustrine waters contain so much as one gram of solid matter per liter, and in five cases only does it exceed .3 gram per liter. There are notable variations in the amount and kind of dissolved matter depending upon the character of the basin, and there are notable variations in the same lake in different seasons, and in different parts during the same season. In the summer the warm waters in the upper portions of the lakes are poorer than the colder waters below, in some of the dissolved substances, especially $Ca\ CO_3$ and SiO_2, while in winter the solutions are nearly uniform throughout. In general, the lake waters have less solid matter in solution than the inflowing rivers, showing that dissolved matter is lost in the lakes. This loss is attributed largely to precipitation, and it seems to be implied that calcareous tufa is of very common occurrence. This would hardly hold for the greater number of the lakes in the United States. With reference to dissolved gases, the conclusion is reached that the amount of these gases, chiefly CO_2, O, and N, are independent of pressure, but that they increase with depth on account of the lower temperature. The amount of carbonic acid gas dissolved far exceeds that of oxygen and nitrogen together, whether measured by weight or by volume. Little account is taken of other gases.

X. *Geological position and origin.*—The classification of lakes in general is briefly outlined, and the lakes of France fitted to the classification. Two primary classes of lake basins are recognized: (1) Those produced by barriers of one sort and another, and (2) rock basins. Of the barrier basins there are many types, most of which are represented in France. The barriers are of various types as follows: (1) *Landslides.* Lake basins produced in this way are found in the Alps, the Juras and the Pyrenees, but are not numerous. (2) *Ice.* No existing lake in France owes its existence to an ice barrier. One extinct lake is so classed. (3) *Moraines.* The moraine of an existing glacier is the barrier which gives origin to a single lake,—Lac Long in the Alps. Lakes which owe their origin to moraines of extinct glaciers are numerous and of several classes. Here belong (*a*) lakes in valleys which were occupied by glaciers, the moraine forming a dam at the lower end of the lake. Of this class there are several representatives in the Alps,

the Juras, and the Vosges Mountains, one in the central plateau, and one in the Pyrenees; (*b*) lakes which result from the blocking of a lateral valley by the moraine of the glacier which occupied the main valley. Of this there are representatives in the Alps, the Juras, and the Pyrenees; (*c*) lakes which lie in basins occasioned by the irregular deposition of drift. But two lakes fall into this category, one in the Alps, about which there is some question, and one in the Juras. In our own country lakes of this class are more numerous than any other. (4) *Lava.* Several lakes, the basins of which are formed by lava dams, are found in the central plateau. (5) *Volcanoes.* Two lakes in the central plateau owe their origin to growth of volcanoes in the bottoms of valleys. (6) *Craters.* Several lakes in the central plateau occupy craters. (It is not altogether clear why crater lakes should be classified among the lakes produced by barriers). (7) *River alluvium.* Lakes formed along rivers by the deposition of alluvium are represented by a few lakes in the Alps, Juras and along the Mediterranean coast. (8) *Bars.* A few lakes on the coast owe their origin to the construction of bars which shut off a portion of the sea water, leaving inland basins. (9) *Dunes.* There are several lake basins completed by dune barriers along the Atlantic coast.

Of the lakes which occupy basins in the rock, one group owes its origin to internal forces. In this category belong the basins produced (1) by violent volcanic disturbances, such as explosions, of which there are several examples in the central plateau; and (2) lakes produced by secular movements. To this class belong several lakes in the Alps (Geneva and d'Annecy), and in the Juras, though concerning the origin of the latter there seems to be some question. Of the lake basins originating through the action of external forces, there are (*a*) those resulting from solution effected by underground waters, represented in the Alps and along the Atlantic coast, in the Juras, along the Mediterranean, and in one or two other places; (*b*) lakes due to erosion of rock along fissures, as where a fissure crosses a watercourse; and (*c*) basins due to excessive local erosion by the ice, represented in the Alps by several examples, in the Juras by one possible example, in the Vosges by one, in the central plateau by several, and in the Pyrenees by a considerable number. Here belongs Lac Bleu, of extraordinary depth. It is probable that in the production of many of the lake basins more than one factor has been involved.

XI. *The life history of lakes.*—After a consideration of the various causes which may bring the life of a lake to an end, the history of a few of the principal lakes of France is sketched. The level of Lake Geneva has been lowered about 30 meters since the glacial time. It had one stationary level between the highest and the present levels, when the water stood 10 meters higher than now. The other lakes especially considered are Bourget, which has also been lowered in post-glacial time, and d'Annecy, which was formerly 15 meters lower than now. The rise was occasioned by alluvial deposits in the valley of the Fier, to which the outlet of the lake flows. These deposits have dammed the exit. The history of Lacs de Saint Point and Remoray —in the Juras—is also outlined, the interesting point being that they were formerly one lake, now divided into two by the growth of a delta completely across the narrow basin. The growth of deltas seems to have played a large part in the history of many of the mountain lakes. This is the natural course of events where torrential streams debouche into the standing water. Many other lakes appear to have had their areas greatly diminished by similar processes. Reference is also made to certain extinct lakes, and the criteria by which their former existence is recognized are briefly given.

The figures in the text of the volume are largely half tones, which unfortunately, cannot be said to be of more than medium grade. It could have been wished also that the few maps of the text which show features other than the topography of the lake bottoms, could have been clearer. On the whole they have so much ink, that it is difficult to find the points sought. It is always a serious problem to make a map clear, and at the same time get a great deal on it, and in this case the difficulty has not been overcome.

R. D. S.

On the Building and Ornamental Stones of Wisconsin. By. E. R. Buckley, Ph.D., Madison, Wis., 1898. Pp. xxvi + 544. Bull. No. 4. Economic Series No. 2 of the Wisconsin Geological and Natural History Survey.

Dr. Buckley's report is one of the most compendious volumes on the subject of building stones published in recent years. Of the three parts into which the subject-matter is divided the first treats of the demands, uses, and properties of building and ornamental stones in general. This is a valuable though brief discussion of the subject.

Part II, which forms the bulk of the volume, begins with a chapter on the geological history of the state, followed by a detailed description of the different quarry-areas. The igneous and metamorphic rocks are first enumerated and described, and the author clearly shows the variety as well as the architectural beauty and value of the granitic rocks of the state. The only metamorphic rock mentioned is quartzite.

The sandstones are divided into three classes, partly on a geographical and partly on a geological basis. The first class includes the northern Potsdam sandstone, comprising what is ordinarily known as the Lake Superior brownstone, which apparently differs quite markedly from the sandstones of the southern Potsdam area and the St. Peter's formation included in the second and third classes. Neat sketch maps show the location of the quarries with reference to the markets and the transportation facilities. The limestone quarries are conveniently divided on a geological basis into (1) the Lower Magnesian, (2) the Trenton, and (3) the Niagara.

Chap. VII relates to the areas from which suitable stone for different uses may be obtained, such as building stone, bridge stone, paving blocks, etc. It has a direct economic bearing that will no doubt be appreciated by architects, builders and dealers in stone.

In the next chapter there is a discussion of the results of physical tests which are conveniently summarized at the end of the chapter in a series of thirteen tables. The crushing strength may really have little significance to the scientist, but has great weight with the architect. In this respect the Wisconsin granites and limestones have shown surprising results. The excess of strength of the Wisconsin granite over that from other states is possibly not so great, however, as the tests might lead one to believe. Granting that Gilmore's formula is incorrect, it is not conclusive proof that a large cube is not stronger than a small one in a ratio greater than the comparative areas of the faces. It might have been better to have given the dimensions of the cubes of the granites tested from other states along with the figures quoted and permit the reader to draw his own conclusions.

One of the most important sections of the report has to do with the effects of freezing and thawing on the strength of building stones. Numerous experiments have been made leading to the conclusion that freezing and thawing, continued for a considerable period, lessen the strength of rock, and that the loss in strength is in a general way proportional to the crushing strength of the rock. In other words, the

loss of crushing strength is greater in rocks in which the porosity is low and the size of the pores small, than in rocks in which the pore space is high and the pores large. This conclusion is diametrically opposed to that which is popularly current. The explanation of this unexpected result is that in the case of rocks where the pores are large the included water is given off with sufficient rapidity to avoid the evils of freezing, while in the case of close-textured rocks which are saturated when frozen, the water does not escape, and the injury to the rock is greater. This is a point of great practical value, as well as of theoretical interest. The results of the experiments are given in detail in tabulated form. Part II also contains a set of tables in which are given the results of the various other physical tests to which the building stones of Wisconsin have been subjected.

Part III is an appendix in which composition, kinds of stone, and rock structures are discussed.

The form of the report is a convenient one, the binding is neat and attractive, the illustrations are numerous and for the most part well chosen. A carefully prepared map of the state is folded in the text. An attractive feature is the representation of the stones in their natural colors. No verbal description could arrest the attention so effectually or give the reader so vivid an idea of the beauty of the stone, as these artistic plates. If the printer is not at fault, however, one might wonder why the beautifully colored granite on Plate XII should be called gray.

The person who can write a perfect report on building stones has not yet attempted it. In Dr. Buckley's report there are some points which some of his readers might wish to change. Some are matters of personal taste and all are of somewhat minor importance compared with the much valuable matter forming the body of the report. Petrographers may not all agree entirely with the distinction between gabbro and diabase (p. 447). Some of the readers may not agree with the relative importance placed upon the different cements in sandstone given on p. 450, or with the conclusions about the use of quartzite on p. 455. All those who might agree with the author that "the joints in igneous rocks are more numerous than in the sedimentary" might not agree with him that it is "owing to the greater length of time through which they have been subject to dynamic action" (p. 459).

The report represents a vast amount of careful and conscientious work on the part of Dr. Buckley and will no doubt prove a valuable

handbook in the stone trade of Wisconsin. While it is prepared primarily in the interests of the stone industry of Wisconsin, it has much of general interest to persons outside of the state, and both Dr. Buckley and the director of the Wisconsin Geological and Natural History Survey are to be congratulated on presenting to the public such an interesting, attractive and valuable contribution on the subject of building stones.

T. C. H.

Irrigation and Drainage. Principles and Practice of their Cultural Phases. By. F. H. KING. The Rural Science Series. The Macmillan Company, pp. 502, 8vo. 1899. Amply illustrated.

In this work there is brought together a vast amount of experimental and experiental data relative to the physics of soils and their relations to water and air. These data are given in both their analytical form in the shape of tables, diagrams, and other modes of scientific expression, and in their concrete industrial form as exemplified in growing crops and in drainage and irrigation appliances. The treatment is very clear and specific and at the same time very compact. It is a conspicuous example of *multum in parvo*, if 500 close-set pages do not make the expression inapplicable. The author has personally studied the irrigation systems of Europe as well as those of this country, and has himself conducted careful experiments bearing on the fundamental principles involved. While thoroughly practical in its bearing, the treatment is firmly controlled by the scientific spirit. It is an admirable blending of good science and good technology.

T. C. C.

The Coos Bay Coal Field, Oregon. By JOSEPH SILAS DILLER. Extract from the Nineteenth Annual Report of the U. S. Geol. Survey, 1897–8, Part III, Economic Geology.

This paper deals almost wholly with economic interests of a very local character; and yet it is not without some facts of general interest. It is a description of a coal field of very limited extent situated on the coast of Oregon 200 miles south of the Columbia River. The coal is of Eocene age. Fossils of fresh and brackish water type are found in

immediate connection with the coal, while marine shells are found in the sediments separating the beds.

The seams contain true coal and "pitch coal." The true coal is of good quality, containing little ash. Much of it is "fat," containing as high as 66 per cent. of volatile matter. The "pitch coal" is found in veins and irregular masses in or near the true coal. The latter part of the paper is devoted to a discussion of the "pitch coal" by William C. Day, who concludes that it is an *asphalt*, as it shows none of the characteristics of coal.

W. T. LEE.

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THE

JOURNAL OF GEOLOGY

FEBRUARY—MARCH, 1900

THE NOMENCLATURE OF FELDSPATHIC GRANOLITES.[1]

Most petrographers agree that the classification of granular rocks, if not of lavas, should be based on mineral composition. This resolves itself practically into the molecular composition. When we state that a rock is composed of quartz, mica, and orthoclase in certain definite proportions, we state the relative proportions of the molecules of which these minerals are composed, and this is true of all other minerals which are made up of a single molecule. But when we introduce terms such as plagioclase, which is composed of two molecules in ever varying proportions, we no longer treat of molecules as such, but of mixtures of molecules. It seems quite clear that the molecular method should be applied throughout, when practicable, and in calculating the composition of the feldspathic rocks the plagioclase should be resolved into the constituent albite[2] and anorthite molecules, and the term *plagioclase* should not be used. This is particularly necessary with monzonites and diorites, for it is clear that if we define typical monzonite as a rock composed of equal quantities of orthoclase and soda-lime feldspar, we may

[1] Published by permission of the Director of the U. S. Geological Survey.

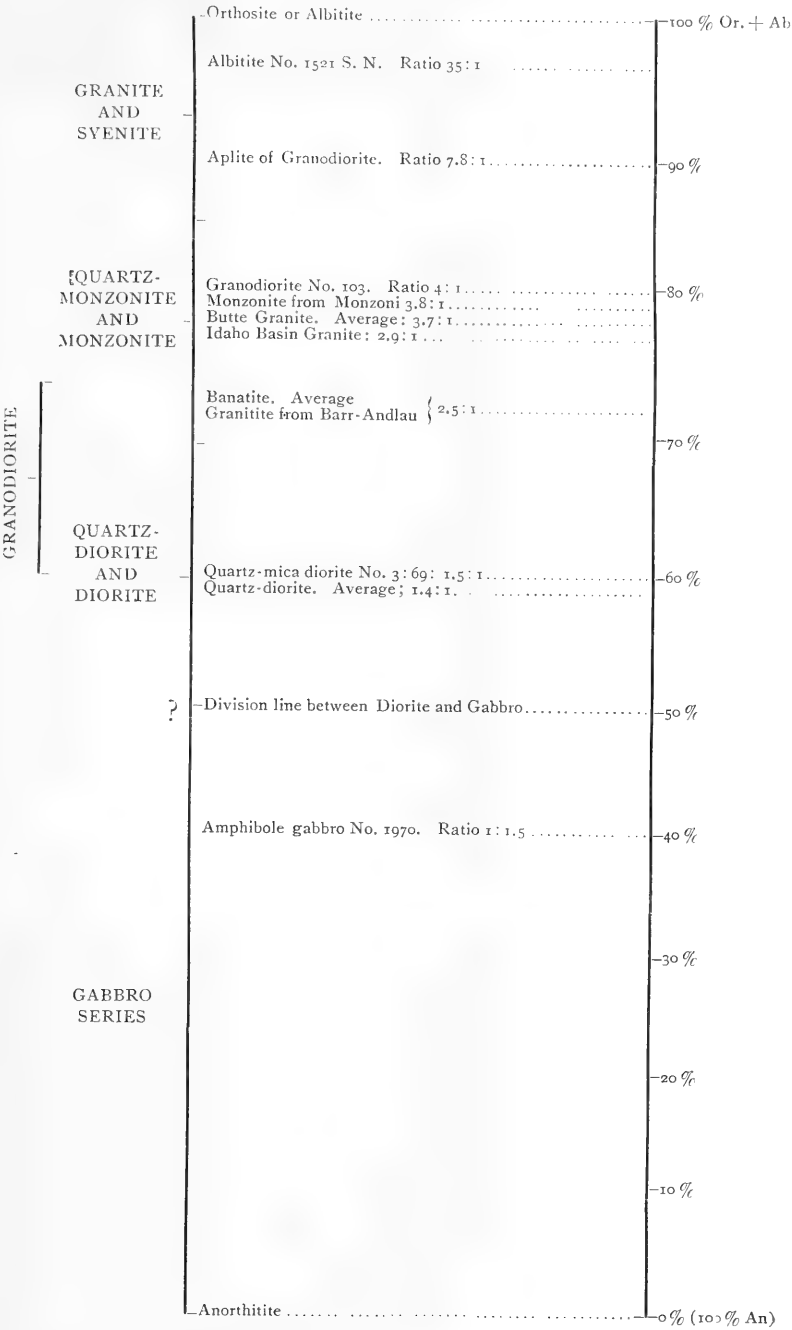
[2] We may treat the soda of the feldspars all as in albite, although some of it may be in the orthoclase.

have orthoclase with basic labradorite, although that must be rare, or, orthoclase with acid oligoclase. The nature of these two rocks would be so different as certainly to make us hesitate to designate them by the same name. In the feldspathic rocks it seems to me proper to base the classification of these rocks primarily on the feldspars, and if we subdivide the feldspathic rocks on the basis of the ratio of the alkali-feldspar molecules (Or + Ab) to the lime-feldspar molecules (An), the true mineral and, to some extent, the chemical relations of the rocks will be brought out, and I think more correctly classify them than to put the orthoclase, or the alkali-feldspars in apposition to the albite and anorthite molecules combined. In order to graphically represent the position of the various rocks under discussion there is now introduced a table which is self-explanatory. In the column represented in the table we have at one end of the series an alkali-feldspar molecule and at the other end a lime-feldspar molecule, and the feldspars of rocks may be said to be composed of one of these molecules or of isomorphous mixtures of the same. The rocks at the head of the column containing feldspars composed chiefly of orthoclase and albite may be designated as orthosite (from the French term orthose = orthoclase) when orthoclase chiefly is present; as anorthosite,[3] when anorthoclase chiefly is present, and as albitite when albite chiefly is present. The rock at the foot of the column, whose feldspathic constituent is largely anorthite, may be designated anorthitite.

It is impracticable at the present time, and, for the purpose of this paper, unnecessary to consider the position in this column of all the feldspathic granolites; a sufficient number, however, are introduced to show the result of the method here proposed, as follows:

Albitite-porphyry or *soda-syenite-porphyry.* — No. 1521 Sierra Nevada. Turner. Seventeenth Ann. Rept. U. S. Geol. Surv., Part I, p. 727. Composed

[3] The use of this term will be at once objected to by petrographers since it has already been used for rocks composed largely of labradorite and more basic feldspars. It is a question, however, since the term in this sense is a misnomer, if it would not be well to drop it.


Orthosite or Albitite
100 % Or. + Ab
Albitite No. 1521 S. N. Ratio 35 : 1
GRANITE AND SYENITE
Aplite of Granodiorite. Ratio 7.8 : 1
90 %
QUARTZ-MONZONITE AND MONZONITE
Granodiorite No. 103. Ratio 4 : 1
80 %
Monzonite from Monzoni 3.8 : 1
Butte Granite. Average : 3.7 : 1
Idaho Basin Granite : 2.9 : 1
GRANODIORITE
Banatite. Average
Granitite from Barr-Andlau
2.5 : 1
70 %
QUARTZ-DIORITE AND DIORITE
Quartz-mica diorite No. 3 : 69 : 1.5 : 1
60 %
Quartz-diorite. Average ; 1.4 : 1.
?
Division line between Diorite and Gabbro
50 %
Amphibole gabbro No. 1970. Ratio 1 : 1.5
40 %
30 %
GABBRO SERIES
20 %
10 %
Anorthitite
0 % (100 % An)

chiefly of albite with some aegerite (?). Ratio of the orthoclase and albite molecules combined, to the anorthite molecules, 35 : 1.

Aplite.— Average of two analyses of aplites from dikes in the Sierra Nevada granodiorites. Composed of quartz > orthoclase > albite > anorthite. JOUR. GEOL., Vol. VII, 1899, p. 160. Ratio, 7.8 : 1. This is the most alkali rich granite in the Sierra Nevada. The amounts of feldspars here given are the result of a more exact calculation, and differ somewhat from the amounts given in the paper referred to. The biotite-granite of my former paper is in reality a quartz-monzonite, and its molecular composition likewise requires some revision.

Granodiorite.— Lindgren. No. 103, Pyramid Peak. Amer. Jour. Sci., Vol. III, April 1897, pp. 306 and 310. Ratio, 4 : 1. Composed of orthoclase > quartz > albite > anorthite.

Monzonite.— Brögger, from Monzoni, described by him on page 24 of "Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol," with a ratio of 3.8 : 1. Composed of orthoclase > albite > pyroxene > anorthite > lepidomelane > hornblende > magnetite > quartz > apatite, zircon, etc. This is taken as Brögger's typical monzonite.

Butte-granite or *quartz-monzonite.*—Weed. JOUR. GEOL., Vol. VII, 1899, pp. 739 and 744. Average of four analyses of the granitic rock at Butte, Montana. Ratio, 3.7 : 1. Composed of quartz > albite > orthoclase > hornblende > anorthite > biotite, titanite, and apatite.

Idaho Basin granite.— Lindgren. Eighteenth Ann. Rept. U. S. Geol. Surv., Part III, pp. 640–641. Ratio, 2.9 : 1. Composed of albite > quartz > anorthite > orthoclase > hyalophane, apatite, titanite, magnetite, and calcite.

Banatite.— Brögger. Average of analyses of five banatites. JOUR. GEOL., Vol. VII, p. 149. The potash and soda given in the paper referred to are interchanged in both the average of the banatites and of the adamellites. Ratio, 2.5 : 1. Calculation approximate.

Granitite.— From Barr-Andlau. Rosenbusch. Die Steiger-Schiefer. Abhandlungen zur geologischen Specialkarte von Elsass-Lothringen, Vol. I, pp. 147–148. Ratio, 2.5 : 1. This appears to be the rock referred to by Brögger on page 62 of his paper on the Monzoni rocks. He states that it contains 35.5 per cent. of orthoclase; 31.5 per cent. plagioclase ($Ab_2\ An_3$); 24 per cent. quartz; and 10 per cent. magnesia-mica. Rosenbusch, however, in the paper above referred to states that this granitite contains about 27 per cent. orthoclase, 40 per cent. plagioclase, 24 per cent. quartz, and 10 per cent. magnesia-mica. The rock represented in the table below, therefore, is Rosenbusch's Barr-Andlau rock, and not the rock discussed by Brögger on page 62 of his paper.

Quartz-mica-diorite or *basic granodiorite.*— Turner. Seventeenth Ann. Rept. U. S. Geol. Surv., Part I, p. 724. Rocks of this type are to be found

ALKALI AND LIME CONTENTS OF FELDSPATHIC GRANOLITES.

Name following new scheme	Albitite-porphyry	Granite or Aplite	Quartz-monzonites and monzonites						Quartz-diorite		Amphibole-gabbro
Original name of author........	Albitite-porphyry, No. 1521 Turner	Aplite Turner	Granodiorite No. 103 Lindgren	Monzonite from Monzoni Brögger	Butte granite average Weed	Idaho Basin granite Lindgren	Banatite, average Brögger	Granitite Barr-Andlau Rosenbusch	Quartz-mica diorite, No. 369 Turner	Quartz-diorite average Turner	Amphibole-gabbro, No. 1970 Turner
K_2O.......	.10	5.40	3.66	4.42	4.11	3.02	3.48	4.54	1.76	2.01	.22
N_2O........	11.50	2.74	3.47	3.07	2.76	3.57	3.57	2.46	3.49	3.07	2.75
CaO........	.55	1.49	3.60	8.50	4.20	3.85	4.15	3.81	5.49	6.00	13.02

PERCENTAGE WEIGHTS OF THE FELDSPAR MOLECULES AND THEIR RATIOS.

Orthoclase...	.56	31.41	17.75	30.00	19.88	10.06	20.57	26.98	10.01	11.12	1.28
Albite.......	96.94	23.16	29.41	19.20	22.98	30.25	29.87	20.94	28.34	25.68	22.53
	97.50	54.57	47.16	49.20	42.86	40.31	50.44	47.92	38.35	36.80	23.81
Anorthite....	2.78	7.00	11.91	12.80	11.48	13.88	20.57	19.04	25.02	27.80	36.58
Ratio of Or + Ab : An.	35 : 1	7.8 : 1	4 : 1	3.8 : 1	3.7 : 1	2.9 : 1	2.5 : 1	2.5 : 1	1.5 : 1	1.4 : 1	1 : 1.5

at a great number of points in the granodiorite areas of the Sierra Nevada. Ratio, 1.5 : 1. Composed of albite> anorthite> quartz> orthoclase><biotite, amphibole, etc. Calculation approximate.

Quartz-diorite.—Turner. Average of five analyses of quartz-diorite from the Sierra Nevada. JOUR. GEOL., Vol. VII, 1899, p. 149. Ratio, 1.4 : 1. Composed of anorthite> albite> quartz> = orthoclase. In most of the quartz-diorites there are biotite, hornblende, and accessory minerals present. Calculation approximate.

Amphibole-gabbro.—No. 1970 Sierra Nevada. Turner. Am. Jour. Sci. Vol. VII, 1899, p. 297. Ratio, 1 : 1.5. Composed of amphibole> anorthite> albite> orthoclase. There are also present magnetite, pyrite, and pyrrhotite. Calculation approximate.

Taking the monozite from Monzoni as a typical mozonite with a ratio of $(Or + Ab)_{3.8} : An_1$ it is clear that if we accept the method here proposed the granodiorite No. 103, the Butte granite, and the Idaho Basin granite are properly quartz-monzonites. If we likewise place the banatites with quartz-monzonites, then the granitite from Barr-Andlau, and many of the granodiorites of the Sierra Nevada will likewise be quartz-monzonites.

The use of mineralogical terms in naming granolites of simple composition seems to me very desirable, although it is not practicable with rocks of complex composition. This can be done with most feldspathic types as follows:

Orthosite	composed	chiefly	of orthoclase
Anorthosite	"	"	" anorthoclase
Albitite	"	"	" albite
Oligosite	"	"	" oligoclase
Andesinite	"	"	" andesine
Labradite	"	"	" labradorite
Anorthitite	"	"	" anorthite

By the addition of abundant and essential quartz to the above ingredients we have appropriate names for the quartz-granolites as follows: quartz-orthosite or granite in its restricted use, quartz-andesinite, quartz-labradite, etc. In all the above cases the quartz is an essential and not an accessory ingredient. When accessory constituents are used in naming rocks the word

should, it seems to me, have the adjective form, as *quartziferous syenite* for a syenite containing some quartz. If such a scheme came into general use the term *granite* would still be a useful one for nearly all quartz-feldspar rocks, in which sense it is used by Michel Lévy and by many other geologists.

H. W. TURNER.

THE GEOLOGY OF THE WHITE SANDS OF NEW MEXICO

East of the San Andreas and Organ mountains of New Mexico is an extensive valley that has been the subject of much discussion from the practical as well as the theoretical point of view. The writer is not aware that any competent geologist has had the opportunity to make an exhaustive study of its unique features and ventures to put on record the results of a somewhat careful if cursory examination of the valley and its environs.

Our first visit was made by wagon from Socorro, the seat of the county of the same name, by a route which afforded ample opportunity to observe the varied geological conditions of the region to the north and east. East of the Rio Grande, after leaving the immediate valley of the river, the Tertiary red marls are encountered, and lie in rather low terraces upon the foot of the greatly disturbed red beds of Permian and Triassic age. These beds are tilted and greatly faulted, leaving one in doubt as to the sequence at this point, especially as there are curious beds of fire clay and shale filled with a varied flora of carboniferous habit consisting of numerous species of Lepidodendrids as yet not worked out specifically.

The lower part of the Permian is composed of limestones and sandstones capped by anhydride and gypsum beds, the former being in some places massive and upwards of fifty feet thick. Extensive exposures of what is apparently carboniferous limestone constitute the principal axis of the low range at this point, and are followed by the red beds over a large area on the eastern side. These beds, as everywhere in the territory, are impregnated with salt and saline alkalis as well as gypsum. The springs are nearly always salty, and lower flats are covered with "alkali." Passing southward, in the immediate valley of the Rio Grande, near San Antonio, is the remarkable basin of

so-called tripoli described by the writer some years since. There is no reason to alter the opinion then expressed that this fine-grained scale-like deposit is the result of the attrition of the floating pumice which forms the surface of the deposit. In fact, in several other places in the Rio Grande valley similar beds on a smaller scale have been encountered, and in each case the material could be traced directly to the acid scoria of the period of trachite eruption.

To the southeast we pass to the celebrated Carthage coal belt, at which point a collection of Cretaceous fossils was made, but, as they were not found in immediate connection with the coal beds, it is impossible to decide what is the age of the coal upon that basis alone. However, a little farther south in the vicinity of Engle and East of the Caballo Mountains fossils of the Laramie age seem to prove that the coal fields at this point are of that period.

At San Marcial and at frequent intervals down the valley are basaltic cones which have broken through the Tertiary gravels and marls and supplied the material for the sheets of lava so characteristic of the entire territory. It is easy to see that they follow in a general way axes of weakness extending north and south, but it is not so easy to determine the reason for a sudden return to highly basic conditions after a gradual increase in acidity in the volcanic flows of the territory. As the writer has shown in several papers, the sequence is from an augite-andesite or diabase through trachite and pitchstone and obsidian to rhyolite. The soda-syenite and phonolite may perhaps form a transition from the andesite, though the occurrence of the soda series is less general

It suggests itself to the writer that the serial arrangement is to be attributed to an invasion of the silicious crust by the internal heat, and that progressively less of the deeper material was involved in these flows until it may be said that that chapter of igneous activity was closed by the rhyolite eruptions. Long after, perhaps as a result of the differential strain of glaciation and its attendant shifting of the axes of rigidity of the crust,

deep crevices were formed entirely through the acid crust and permitted a slow and relatively quiet overflow. This method of eruption would account for a considerable degree of fluidity of the lava and for the very slight surface disturbance. However this may be, the flows of lava, usually of slight thickness, are often of enormous extent, and where water has had access to the loose materials beneath, the characteristic *mal pais* results.

Our way is now across the Jornado del Muerto, the perils of passage being greatly reduced by the sinking of wells for ranches at various places, though the terrors of a blizzard on these barren treeless plains needs but to be experienced to be appreciated. Though comparatively arid and seemingly barren, the short grass furnishes a good subsistence to many herds of both cattle and horses.

Rising by a rather moderate slope from the plain are the foothills of the great range which begins with the Sandias east of Albuquerque and is continued in a broken line by the Manzanos, the Oscuros, the San Andreas, and the Organs. In the Sandias and Manzanos the granite, everywhere lying at the base of the stratified rocks, so far as known, in the territory, is exposed in an extensive escarpment on the east side of a very important fault line and the superincumbent stratified rocks dip rapidly to the east. In both the ranges mentioned the rock lying upon the granite, or its gneissic or schistose equivalent, is a quartzite whose materials seem not to have been derived from the subjacent granite, but from a schist or quartz rock which we suppose to have been the superficial portion of that series. The age of the quartzite, as well as that of the granite, must at present remain a matter of conjecture in spite of poorly preserved fossils in the limestone layers found in one or two instances in the midst of the granite. Reposing on the quartzite conformably in the Sandia and Manzano ranges is a silicious series with a few limestone bands whose fossils seem to be of undoubted Coal Measure age. This is followed by a dark conchoidal limestone with shales having a fauna similar to that of the Upper Coal Measures in Ohio as will be more particularly set forth in another

place. The lower series we have called the Sandia series from the place where best seen. Some distance above the dark lime is a sandstone or conglomerate which is rather inconstant in thickness and may be absent, but which roughly marks the transition to the permo-carboniferous as generally developed in all the ranges under consideration. This Coyote sandstone is particularly well seen in the canyon of that name in the south end of the Sandias. Above this is the large series of massive gray and silicious lime at whose base it is usual to find a large form of Fusulina and, a little higher up, a well defined zone characterized by the bryozoa preserved on the faces of the cleavage slabs. Here begin the evidences of a transition to the Permian as indicated by the presence of *Mekella striatocostata*, *Terebratula bovidens*, *Productus punctatus*, and a variety of forms which are mingled with fossils also found in the carboniferous below. At the top of the gray lime is a large series of coarse, red quartzites and sandstones interbedded with dark earthy limestones and shales. There are few fossils except petrified wood and the few found still preserve a carboniferous habitus. This Manzano series is everywhere in evidence where a sufficiently high horizon is reached but is often removed from the crests of the range while it occurs in the eastern faulted extension. Following this is the group of red quartzites, sandstones, shales, and marls which we have recognized as the equivalent of the "red series" of Texas and Kansas. Three divisions can be made out in all parts of the territory examined which have been named from their prevailing or characteristic color, though it is not to be supposed that the color mentioned is constant. The lower or "red bed" division still retains some bands of limestone or lime breccias, the latter being a very characteristic element. Some 500 feet may be estimated as the average thickness of this division and prior to the work recently done in the valley of the white sands we had no definite evidence as to the age of the entire division. We only knew that a narrow bed of quartzite near the base at a point east of the Sandia Mountains contained the well-known Permian forms such as *Bakvellia parva*, *Myalina attenuata*, *Pleurophorus*

subcuneatus, etc. The major portion of the series proved obstinately barren. At the top of this division there are found in the most widely distant parts of the territory enormous deposits of gypsum and salt. In fact the presence of salines may be said to characterize the series, but especially at the passage from the red into the chocolate beds above it. The chocolate series has a thickness of at least 600 feet and passes through quartzites and gray and red sandstone layers into the loose vermilion marls and clays of the upper division. So far, we have no positive evidence as to the age of the two upper divisions, but may presume the chocolate beds to be Triassic and the vermilion division to represent whatever of Jurassic time is accounted for in the territory or at least in the central portion.[1]

South of the Manzano range the continuity of the uplift is broken so that in the Fra Cristobal and Caballo mountains near the Rio Grande and in the Oscuro range farther east the dip is, as in the Sandias and Manzanos, to the east while in the San Andreas, occupying an intermediate position farther south, the dip is to the west so that the high escarpment with its granite and schistose base faces the great salt plain.

In the interval between the range bordering the river and the Oscuro Mountains we have abundant evidence of the existence of the Cretaceous with its lignitic coals and it may be assumed that the Cretaceous also extends southward on the west side of the San Andreas, though nowhere exposed in the *Jornardo del Muerto*. Passing eastward lower horizons gradually emerge till, as we enter the interval between the north end of the Andreas and the south end of the Oscuros, the red beds are seen in the form of low hills with a dip to the east at the western foot of the Oscuros. Underneath is a part of the Permo-carboniferous. It appears, therefore, that the Oscuro range is separated by a fault line from the axis of the Andreas. On the west side of the San Andreas the red beds are represented as is shown by the extensive deposits of calcium anhydride in the foothills.

[1] It will be remembered that Professor Cope in 1875 identified part of this series as Triassic and that Dr. Newberry described Triassic plants from New Mexico.

The eastern escarpment of the Andreas is bold and irregular in the extreme but the fault which created it seems to have been wavy so that a crenulated or sinuous aspect is presented to the plain. The granite in some instances seems to have escaped in pinnacled or columnar form and throws off the restraining influence of the stratified rock to appear in jagged peaks. This is particularly true in the Organ Mountains where, however, there must be added the influence of a later trachytic overflow. Our examination of the San Andreas was cursory but was sufficient to show that the thickness of the stratified series is greater than in the Sandias and Manzanos. The lower portion is composed of quartzites and silicious shales which may be compared with the quartzites in the Manzanos. Above this is a large series of gray cherty limestones and quartzites of an entirely different texture and appearance. This has baffled our search for fossils in the Andreas and the Caballos where it is also well developed but, fortunately, we have been able to discover in the upper part of this series on the eastern side of the salt plain fossiliferous bands which place the age beyond doubt. Spirifer Grimesi, Leptaena rhomboidalis and other well-known Burlington brachiopods are associated with crinoids of that period in great abundance. Some of the bands are practically composed of the débris of the crinoids.

Above the Burlington there seems to be a hiatus, for the next species encountered are distinctively Coal Measure forms and the sequence from this on to the top is as in the ranges farther north though there seems to be a tendency for the limestone to encroach on the sandy elements and for the individual components to thicken toward the south, a fact which we interpret as indicating deep-sea conditions.

Attention has elsewhere been called to the method of occurrence of the copper found so widely scattered through these ranges. It was shown that the deposits of copper which have attracted so much attention were formed in veins that extend from top to bottom of the sedimentary series but do not seem to cut the granite, at least to any depth or with any regularity.

These veins are so regular that it is conceived that they may be best explained as the result of warping or shrinking in the sedimentary series and it seems certain that they have been filled from above. The vein matter is chiefly calcite, fluor spar, siderite and barite and it is chiefly at the intersection of the vein with a band of iron-filled quartzite, reposing on the granite and forming a definite selvedge to the sedimentary series, that the copper is deposited. The ores include nearly all the common copper compounds, calchocite, malachite, azurite, bournite and cuprite predominating. Here, as in Hannover and Santa Rita, it seems indubitable that the iron, accumulated by leaching, has been the agent in precipitating the copper.

Between the Organ and San Andreas mountains there is an area on either side where the granite is laid bare and it is true that some show of copper may be found in crevices and basins superficially on the granite. It is probable that all, or a great part, of the copper of the two ranges has been originally derived from the red-bed series (Permian and Triassic) by infiltration, for the original existence of the cupriferous series on top of the strata now remaining in the ranges is indubitable. Dikes of diorite cutting through the granite and sedimentaries along or near the fault line have caused portions of the latter to lie in irregular fragments along the foot of the escarpment to the east, the strata dipping towards the dike which served to pry them from their original position.

Standing upon a jutting eminence of the San Andreas and turning eastward one looks out upon a scene difficult to parallel. At one's feet is an enormous plain, apparently as level as a floor, over forty miles wide and extending as far as eye can reach to north and south. On the southern horizon rise the Jarillas Mountains which only partially interrupt the plain, while to the northeast are the snow-capped peaks of the Sierra Blanca. Northward the plain is narrowed by the eastward intrusion of the Oscuro range while it is possible to make out the dark area of basalt which covers that part of the plain to the east and southeast of that range. This is the widely-know "*mal pais*" of

Socorro county which has proven such an effectual barrier to communication between the Rio Grande valley and the growing region of White Oaks. South of the *mal pais* is a great white sea on which one can fancy the glint of white-caps. Such a body of water being out of the question the uninstructed observer would surely think himself the victim of a mirage but we recognize in the snowy area the famous white sands. Curious and conflicting stories are current respecting the area but the truth is not less interesting. We had already been forced to the conclusion that the true origin of the saline and gypsum beds is to be sought in the red series above mentioned. It seemed at first, however, that the geological relations would prove baffling.

Rising abruptly from the level plain on its eastern side are the foothills of the Sacramento range near which pass the trains upon the newly-finished El Paso and Northeastern railway. The escarpment is nearly perpendicular and the dip is very slight and to the east. The bottom of the sedimentary series is not reached, at least in this vicinity, but it is evident from a comparison of this with the western escarpment that the base is not far distant. The section is given in detail below but we were very fortunate in coming upon a locality where the lower portion of the section is fossiliferous About 560 feet from the base, at Dog Canyon, some 12 miles southeast of Alamogordo is a band of crinoidal limestone which, together with the gray lime and quartzite above it, contains numerous, though poorly preserved fossils. Among these enough forms were identified to determine the limestone as Burlington. As nearly as we could determine the Burlington is represented by at least 250 feet. Several intercallary sheets of igneous rock (diorite, with porphyritic hornblende) penetrate the strata and obviously connect with a boss farther east and higher up the canyon. The influence of the intrusive may account for the amount of chert seggregated in this portion of the section but, for whatever cause, the limes are chiefly highly silicious and quartzite has replaced former limestones. Above the Burlington, which is entirely absent farther north, is the entire series of Coal Measure

limestone and sandstone as seen in the Sandia range except that the deeper sea conditions have expressed themselves in greater thickness of limestone. The fossils in the lower part are of mid-carboniferous types but pass somewhat gradually into the assemblage which we have characterized as Permo-carboniferous. *Meekela*, *Terebratula bovidens*, *Productus punctatus*, a large *Bellerophon* and many other familiar forms indicate an approach to the top. Above the measured escarpment but inaccessible to our reach is a series of what appear to be yellowish sandstones or quartzites which may confidently be referred to the Manzano series at the top of the Permo-carboniferous. Northward the dip rapidly veers to the northeast and thus the several horizons drop below the surface and bring still higher ones than those seen at Dog Canyon within reach. About 16 or 18 miles west of the main escarpment is a low ridge of hills which prove to consist of carboniferous limestone but bearing evidence on their western aspect of the fault which brought the plain down to a lower level. This ridge is most instructive in showing that the fault was not a single break but by steps or successive faults. Wells in the plain to the west all show the existence of the red beds both by the presence of salt (often strong brine), but also by the red color of the marl brought to the surface. North of the outlyer spoken of is a most interesting spring which has built up for itself, geyser-like, a mound of some thirty feet above the general level from which issues a quantity of warm and highly saline water which flows into a depression and, sinking from view, leaves a large salt and alkali flat. Other similar lakes are grouped in the neighborhood. The actual character of the deposit is generally masked by a calcareous marl of white or gray color which forms a crust over the entire plain and is highly charged with salts except at the immediate surface.

But passing northward and observing several other saline springs similar to the one described, the route carries us through the intensely modern "boom" town of Alamagordo with its great sawmills fed from the Sacramento Mountains by a spur railroad and the equally typical old Mexican town of Tularosa

where nearly every house is of adobe. The intense red color of the adobe awakened our curiosity and led us to the examination of the escarpment to the east and north. As we hoped, the dip had sufficed to bring to the general level strata which at Dog Canyon were out of reach and the lower third of the red series with its capping of gypsum and salines is at the foot of the section. The following is the section as casually examined during our visit—a section which will yield a large suite of interesting fossils of decided Permian facies, though well-known carboniferous forms extend throughout. Commencing at the bottom, we have first a poorly exposed series of silicious shales and thin-bedded limestones in which is a characteristic Permian assemblage including *Myalina permiana*, *Myalina attenuata*, *Pseudomonotis hawni*, *Aviculopecten occidentalis*, etc.

Then follow, as we ascend:

Reddish shales and loose sands	15 feet
Limestone	6 "
Greenish sandy shale	10 feet
Coarse conglomerate with pebbles of granite, etc.	5 to 10 "
Purple red sand with pebbles	20 to 25 "
Earthy limestone	2 "
Loose red sand	18 "
Coarse red conglomerate	4 to 5 "
Red sandstone	8 "
Loose red sand and shales	18 "
Conglomerate	4 "
Limestone	2 "
Greenish sand	12 "
Earthy lime shales and sand	5 "
Limestone and calcareous shale	6 "
Sandy shale and green sands	35 to 40 "
Well marked bench of gray lime	8 "
Red shale including a very irregular conglomerate	4 to 8 "
Thin bed of lime	1 foot
Green fissile shale	6 feet
(Gypsiferous marl, probably surface deposit)	00 "
Limestone and shale with numerous small fossils	6 to 8 "
Brown or red shale with numerous fossils	35 "
Sandstone	8 "

Shale	6 feet
Sandstone	6 (?) "
Limestone	1 foot
Green sandstone with calcareous band	20 feet
Calcareous zone	00 "
White sandstone	4 "
Shell limestone fossils	1 foot
Nodular marl	15 feet
Nodular limestone	2 "

Our ascent ended here but beyond appeared the gypsum beds reposing upon red and white marls as in the Nacimiento region and elsewhere. Still above and forming separate terraces are the chocolate and vermilion beds, and at the top of the section the lower Cretaceous. The creeks or arroyos which traverse the gypsiferous horizon come laden with salt which is deposited as a white coating upon their beds and banks.

Having satisfied ourselves both as to the age and the character of the deposits which underlie the great plain, we undertook a study of the plains themselves. At the southern end of the *mal pais* which forms the northern boundary of our field of work, numerous springs gush out from beneath the thin sheet of black basalt. These springs differ from those from the salt valley itself, in that the water is not warm nor appreciably salty. It is apparent that the lava has served to retain the water which, on making its way beneath the sheet, has excavated channels in which the water may be heard rushing by one crossing the lava. One of these streams in particular, at Mal Pais spring, forms a considerable creek which supports a varied plant and animal life including fish of considerable size and several crustaceans (Gammarus or the like). The water, before it flows many rods, becomes distinctly salty and bitter. At a little distance to the south begins an area of depression which is forty miles long and receives the drainage from all directions. This whole area is covered with saline efflorescence while all the shallows, when dry, as they are most of the year, have considerable deposits of salt on the surface and the subsoil or under clays are infiltrated with alkaline salts the nature of which will be fully discussed in another place

About one mile from the Mal Pais spring above mentioned is a small salt lake which has furnished the salt for ranches for a radius of many miles during the historic period and at our visit the surface was covered to the depth of an inch or so with pure crystalline chloride of sodium. Still west and forming the western limit of the visible saline beds, is a drainage arroyo whose source seems to be in the red beds that emerge west of the Oscuro Mountains and conveys their saline water to the basin of the sands. Along the course of this arroyo are numerous salinas and alkali flats and these gradually broaden to form what may be described as one vast alkali and salt plain where brine stands for part of the year. Other arroyos come in from the west in some of which, even at the time of our visit, was a considerable quantity of flowing water which is a strong brine unfit for cattle even when accustomed to drink from the saline springs which unwonted animals will reject. Where these arroyos enter the salt lake and along the shores of the lake are bluffs of erosion some of which are over twenty feet high. In these exposures we encounter the red bed formation with its marls and gypsum deposits. Large quantities of pure crystalline gypsum are here exposed and the marls are alkaline and saline. We have therefore local proof, as well as the most conclusive evidence from the environs, that the whole of the plain is in or near the horizon of gypsum and salt that separates the lower from the middle member of the red or saline series.

In the salt flats the ribs of gypsum rise in successive ridges, and the action of the elements soon breaks up the exposed crystals into small grains which are carried by the winds hither and yon. This characteristic of the salinas accounts for the most curious and notable of the many peculiarities of these plains, namely the white sands. These have been attributed to the action of springs and the material has been supposed to have crystallized from solution. It has been suggested that the sands have been collected by floods, but a short examination shows that these great drifts are simply sand dunes collected from the gypsum sand formed as above stated on the surfaces of the lakes. The salt

and alkaline salts are also driven with the gypsum but on account of their solubility they do not remain in the dunes. These dunes lie to the south and east of the flats whither they are driven by the prevailing winds and not only cover a large part of the salinas themselves, but form a growing fringe to the east and south. The dunes are, in the majority of instances, very pure gypsum though there is a small commingling of earthy impurities. The soil underneath is impregnated with salt and soda and salt lakes are scattered over the area covered by the dunes. The intervals between the crests of the ridges support a scanty but very interesting vegetation. Near the southeastern angle of the sands is a very important salt lake which has been known as a source of salt for the ranches for many years. The north and south extent of the "white sands" is about 35 miles while the greatest breadth at the southern margin is about 18 miles. The lines connecting the extreme points are irregular, enclosing roughly a triangle of about 350 square miles. To this may be added nearly as much more of saline land on the west and in isolated areas to the south. The whole plain is geologically of the same nature, but, inasmuch as it is either higher than the basin or is more completely drained (to the south), the saline ingredients are not brought to the surface.

East of the Jarillas Mountains this plain again gives external evidence of its subterranean supply of salines while far to the north, beyond the covering of lava, there are depressions of the same character and of the same geological age and nature. The fact that such depressions occur in New Mexico only in connection with the red beds leads to a suggestion that may be worthy of consideration. It is evident to anyone who has studied the geology and geography of the territory that it is, as Major Powell said long ago, the best drained region in the world. The comparative newness and permeableness of its strata all militate against the formation of local basins. There has been no glaciation to produce local lake reservoirs. Erosion has kept well in advance of secular changes of level and barriers of local origin do not prove capable of retaining the waters which come in

torrential plentitude when they come at all. Some explanation must be sought for the basins found in the saline areas. It might be supposed that such explanation would be found in the depressions resulting from the post-Tertiary lava flows which occur over the entire territory. To this it may be replied that the basalt is certainly of deep origin, for the preceding flows were all acid and the basalt overflows are essentially similar among themselves and demand a common origin at a depth. Moreover the distribution of the flows indicates that the orographic lines of weakness opened were of almost continental extent. The depressions due to the outflow of basalt would not account for the local basins referred to and we are driven to the conclusion that these slight depressions are due to the effect of the removal of the soluble ingredients in these beds themselves.

The discussion of the economic aspects of these beds will occur in the forthcoming bulletin of the University Geological Survey of New Mexico.

C. L. HERRICK.

DESCRIPTION OF PLATES

PLATE I.

Sketch map of the region of the "White Sands" including part of Dona Ana, Socorro, and Otero counties, New Mexico.

PLATE II.

Mostly Permian fossils from exposures near Tularosa and east of the Sandia Mountains in Bernalillo county. These plates are given to illustrate the fauna rather than as a basis for a discussion of the species figured, which have as yet been subjected to no critical study.

FIG. 1 *Pseudomonotis* n. sp. (*costatus*).
FIG. 2. *Bellerophon* sp.
FIG. 3. *Aviculopecten cf. coxanus.*
FIG. 4. *Pseudomonotis radialis* Meek.
FIG. 5. Undetermined.
FIG. 6. Undetermined.
FIGS. 7, 8. *Rhynchonella osagensis* Swallow. Two views.
FIG. 9. *Pleurotomaria cf. subdecussata* Geinitz.
FIG. 10. *Pleurotomaria marcouiana* Geinitz.
FIG. 11. *Rhynchonella* sp. Two views. (*cf. R. osagensis* Swallow).

FIG. 12. *Terebratula ?* sp. Two views.

FIG. 13. *Zaphrentis* sp.

FIG. 14. *Productus cora* D'Orb.

FIG. 15. Portion of the whorl of *Euomphalus* sp.? All the above are from shale number III of the Tularosa section.

FIG. 16. *Bakevellia parva* Meek and Hayden. From base of section near adobe smelter east of Sandia Mountains at the base of the Permian.

FIGS. 17, 18, 19. Undetermined gasteropods from the base of the Tularosa section.

FIG. 20. *Orthoceras* sp. Base of Tularosa section.

FIG. 20 *bis*. (Lower left corner) *Edmondia* sp. Same place as the above.

FIGS. 21, 22, 23. *Meekella striatocostata* Cox. From No. 3, Tularosa section.

FIG. 24. *Myalina permiana*, base of Tularosa section.

FIG. 25. *Bellerophon montfortianis* Norwood and Pratten. Base of section at adobe smelter.

FIGS. 26, 27. *Pleurophorus subcuneatus* Meek and Hayden. Same as the above.

FIG. 28. *Sedgwikia topekaensis* Shum. Shales below upper layers at Tularosa.

PLATE III.

FIG. 1. *Aviculopecten occidentalis* Shum. Left valve.

FIG. 2. *Aviculopecten occidentalis* Shum. Right valve.

FIG. 3. *Pseudomonotis hawni* Meek and Hayden. This and the above from the lowest level of the Tularosa section.

FIG. 4. *Myalina perattenuata* Meek and Hayden. Adobe smelter east of Sandias.

FIG. 5. *Myalina swallovi* Shum. Upper Carboniferous, Sandia Mountains.

FIG. 6. *Discina convexa* Shumard. As above.

FIG. 7. *Gervillia longa* Geinitz. As above.

FIG. 8. *Chonetes granulifera* Owen. As above.

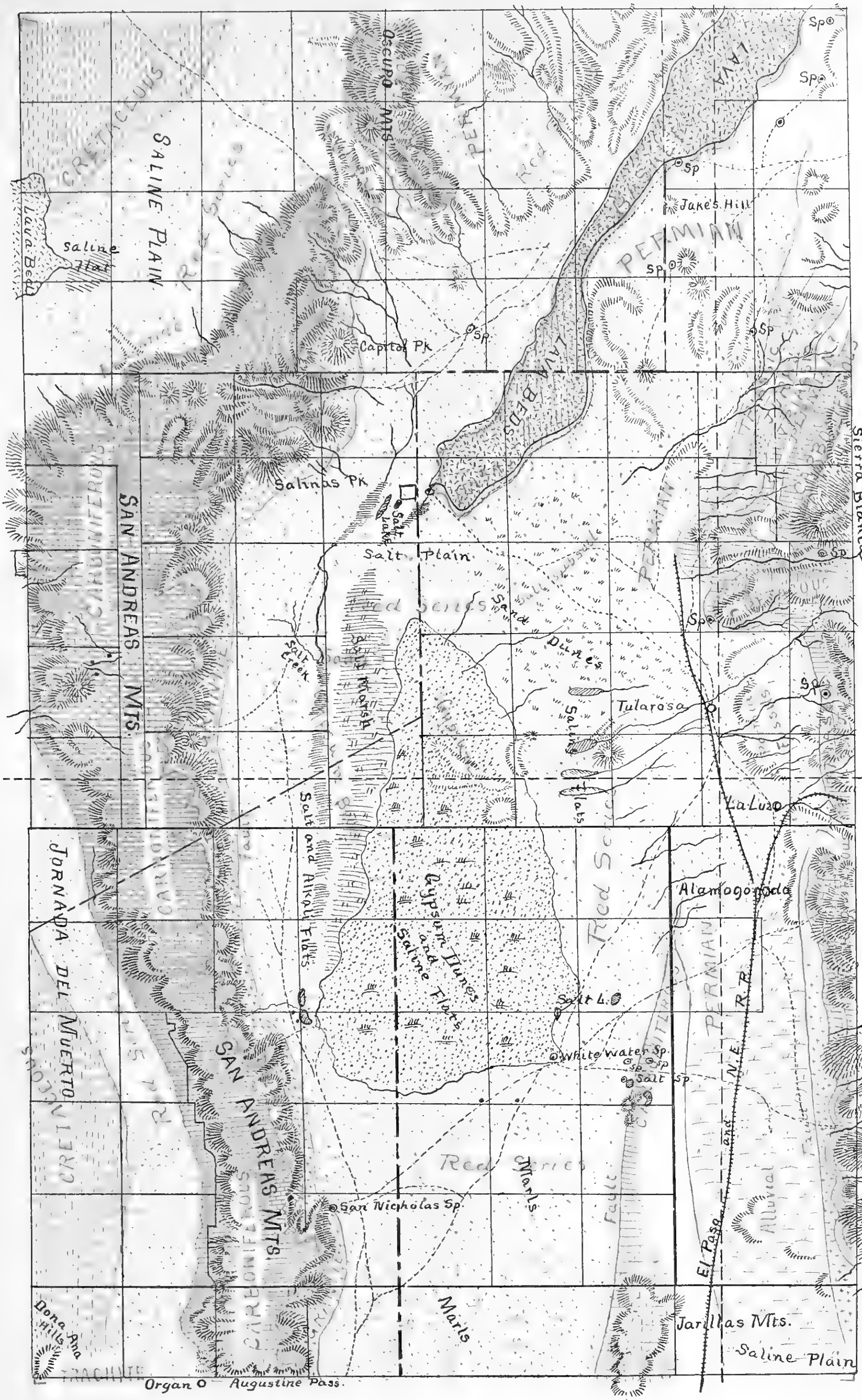
FIGS. 9, 10. Unidentified gasteropod. As above.

FIG. 11. *Myalina ?* Permo-Carboniferous east side of Sandia Mountains.

FIG. 12. *Edmondia* sp. Base of Permian, adobe smelter.

FIG. 13. *Edmondia aspinwalensis* Meek. Permo-Carboniferous. Jemez Spring.

FIG. 14. Unidentified gasteropod. Upper Carboniferous.



Oscuro Mts
Permian
Lava
Sp
Jake's Hill
Permian
Cretaceous
Saline Plain
Red Series
Lava Bed
Saline Flat
Capitol Pk
Lava Beds
Salinas Pk
Salt Lake
Salt Plain
Red Series
Sand Dunes
Sierra Blanca
San Andreas Mts
Salt Creek
Salt Marsh
Tularosa
Saline Flats
La Luz
Jornada del Muerto
Salt and Alkali Flats
Gypsum Dunes and Saline Flats
Alamogordo
Red Series
Permian
Salt L.
White Water Sp.
Salt Sp.
San Andreas Mts
Red Series
Marls
San Nicholas Sp.
Fault
Alluvial
El Paso and N. E. R. R.
Jarillas Mts.
Saline Plain
Marls
Dona Ana Hills
Organ
Augustine Pass

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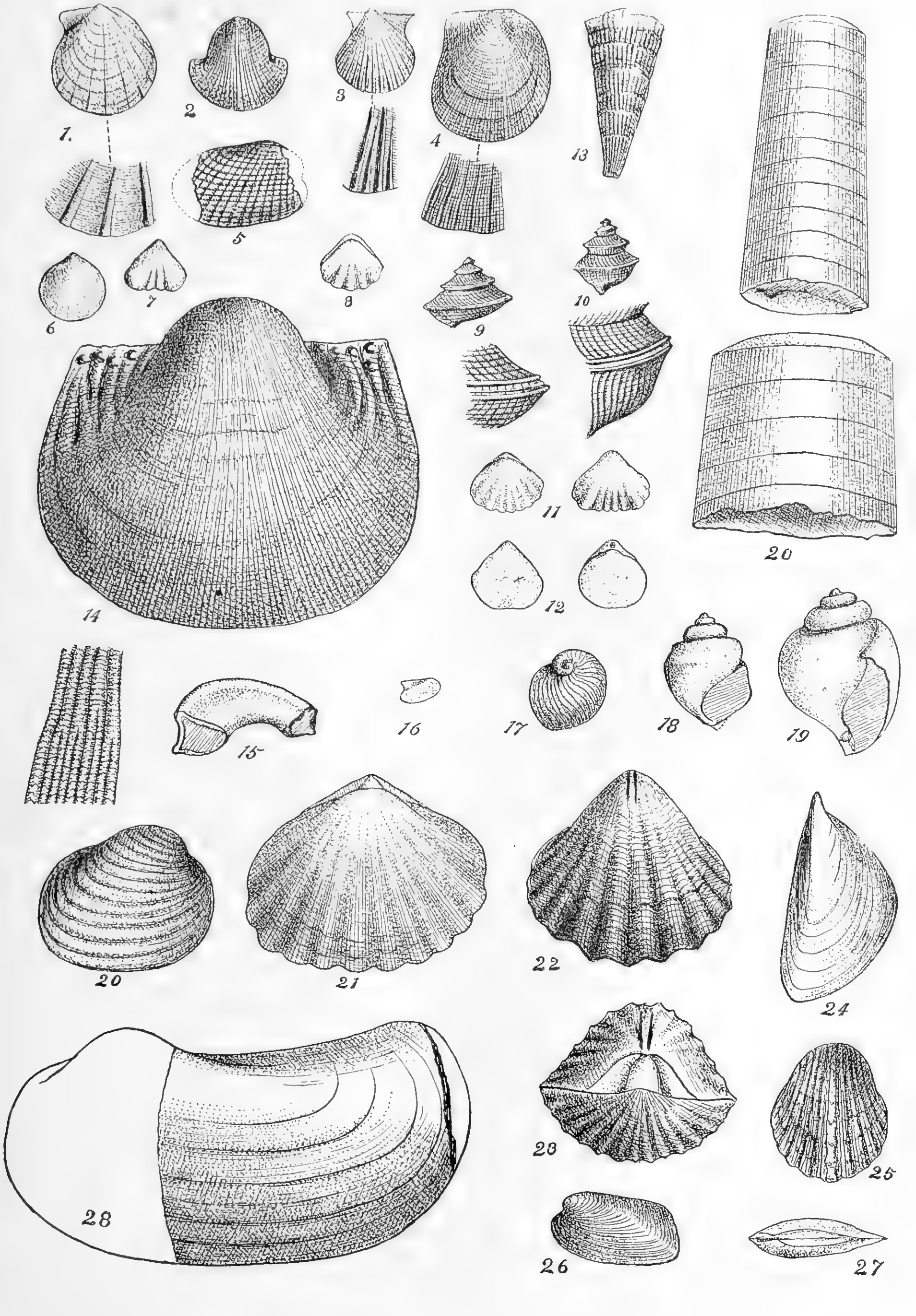
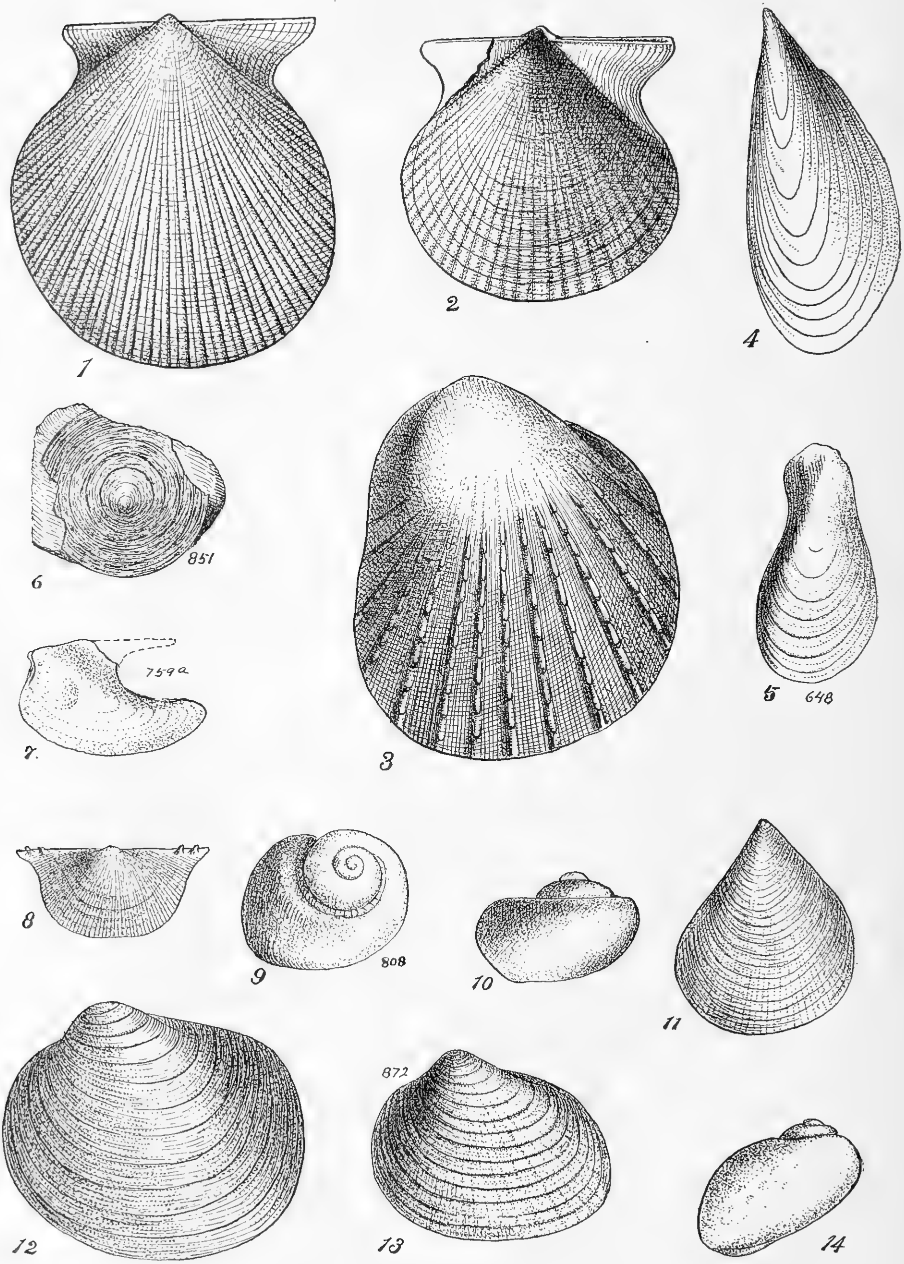
Plate II



Jour. Geol., Vol. VIII, No. 2

Plate III



THE ORIGIN OF NITRATES IN CAVERN EARTHS

Much interest has been taken in the great caverns of Virginia, Kentucky, and Indiana by tourists, and considerable popular literature has been published, especially in description of Mammoth, Luray, and Wyandot caves. In this literature rather frequent allusion is made to the "nitrates" in cavern earths, and occasionally a theory is advanced to explain their origin. Popular interest is awakened in this question by the large amount of "saltpeter" known to have been taken from Mammoth Cave during the war of 1812, and from similar caverns in Alabama and Georgia during the Civil War for the manufacture of gunpowder.

The origin of this supply of nitrates is commonly ascribed to animal remains, and especially to the excrement of bats. In Mammoth Cave, however, the cavern earth was worked for nitrate for a distance of over five miles from the only opening known which leads to the surface, while bats as a rule go but a short distance from the entrance of the cavern. Again, on account of the antiseptic character of the atmosphere of caves, we would expect, in case the nitrate was derived from bats, to find some animal remains, in the form of their dried bodies, their bones, or their excrement; but organic matter of any kind is rare in cavern earths. The hypothesis ascribing such an origin to the vast stores of nitrates taken from Mammoth and other caverns seems, therefore, inadequate.

Caves in limestone regions are due to the solvent action of water containing carbon dioxide. This process must have been very slow and in most cases unaided by mechanical erosion, thus leaving the insoluble portion of the limestone as a deposit on the floor of the cavern. This residue is known as cavern earth.

From the mode of formation of caves, it is evident that this residue must have been washed perfectly free from all salts

readily soluble in water by the water which slowly carried away the limestone itself during the formation of the cavern.

Recent progress in bacteriology and agricultural chemistry has thrown much light upon the origin of nitrates in soils by the oxidation of organic matter in the presence of certain bacteria. The surface soil in cavernous regions is usually loose and porous, and consequently favorable both for nitrification of organic nitrogen and for downward percolation of the surface water. It may not be unnatural, then, to ask whether the nitrates in cavern earths may not have orginated wholly or in part from nitrification of organic matter at the surface and the subsequent leaching of the nitrates so formed into the caverns. Caves would thereby act merely as receptacles for the surface drainage, and provide an avenue for the return of the percolating water to the atmosphere by evaporation. If the nitrates in caves originated in this way, we would expect to find also in cavern earths such other soluble constituents of soils as must necessarily have been leached out along with the nitrates.

By leaching cavern earths with cold water some material is always extracted. The amount thus washed out is sometimes as much as 13 per cent. of the sample. The following analyses are given of the soluble matter of cavern earths derived by washing the samples with cold water, the figures representing percentages :

Source	Calcium oxide	Sulphuric anhydride	Alkalis	Chlorine	Nitric acid	Ammonia
Mammoth Cave, Ky.	1.06	2.16	1.45	0.28	0.37	0.005
Mammoth Cave, Ky.	3.20	4.57	3.04	1.41	1.36	0.001
Saltpeter Cave, Ind.	2.31	3.30	2.26	0.23	1.88	0.007

From these results it is seem that nitrates form only a small portion of the total soluble material in cavern earths.

A kilo of subsoil over Mammoth Cave was placed in a percolator, and two liters of water charged with carbon-dioxide were added and allowed to stand for a week, with frequent stirrings, when the water was slowly drawn off. The water was then

evaporated in a platinum dish and the residue was analyzed. A sample of cave earth collected as nearly as possible beneath the spot where the sample of subsoil was taken, was also treated in the same way. A sample of bat guano and one of the earth occurring just below the guano were subjected to the same treatment. The results of these several analyses are given in the following table, the figures representing percentages of the sample taken:

	Mammoth Cave		Dixon's Cave	
	Subsoil over Mammoth Cave	Cave earth below	Bat guano	Earth below bat guano
Sulphuric acid, SO_3	0.0054	4.16	0.67	0.031
Lime, CaO................	0.0018	2.03	3.34	0.23
Alkalis, Na_2O, and K_2O...	0.00288	2.86	0.37	0.26
Phosphoric acid, P_2O_5.....	trace	0.0003	0.044	0.0137
Ammonia, NH_3...........	0.00192	0.011	0.102	0.019
Nitric acid, N_2O_5.........	0.0068	0.82	6.016	0.0118

By comparing these analyses it is evident that the soluble material in the cave earths might have been leached from the soil above.

The bat guano forms a thin layer over the floor of Dixon's Cave, and is composed of a mixture of excrement and fuzzy material from the bats' bodies, together with sand and earthy matter from the walls of the cavern. Judging from the above analyses, this layer seems to have acted as an excellent absorbent preventing the further percolation downward of material dissolved from the soil above the cave, since the earth below contains very little soluble material.

But guano was found to contain considerable amounts of salts of phosphoric acid soluble in cold water, while the cavern earths proper contain only traces of these salts. The total percentage of phosphate dissolved out of bat guano by dilute acid was found to be about the same as that derived from cave earth by the same treatment. The following results of analyses of bat guano, taken just as it came from the cave, making no attempt to mechanically separate the sand and earthy matters, and of cave

earth, both from Dixon's Cave, were obtained by igniting the dried samples and then treating them with dilute hydrochloric acid.

	Bat guano	Cave earth
Loss on ignition	32.16	6.02
Insoluble residue	40.65	73.80
Soluble silica, SiO_2	1.03	trace
Calcium oxide, CaO	10.95	7.51
Ferric oxide, Fe_2O_3	1.20	3.37
Alumina, Al_2O_3	5.27	2.41
Magnesia, MgO	0.37	0.30
Sulphuric anhydride, SO_3	4.37	2.77
Phosphoric anhydride, P_2O_5	2.62	2.10
Alkalis and loss	2.38	1.72

This sample of cave earth contained no perceptible organic matter.

It seems from a comparison of these analyses that we cannot prove the presence of animal remains by the total content of phosphoric acid soluble in dilute mineral acids, since a residue from limestone must contain considerable calcium phosphate on account of the insolubility in water of this salt of calcium.

Analyses of the water dripping from the roofs of caves were made, and results were obtained which do not vary markedly from results obtained from analyses of ordinary sub-drainage waters. The following is an analysis of the residue from water which dripped from the roof of Mammoth Cave:

	Milligrams per liter
Silica, SiO_2	12.23
Sulphuric Anhydride, SO_3	15.81
Phosphoric Anhydride, P_2O_5	trace
Chlorine	2.71
Ferrous Carbonate, $FeCo_3$	1.02
Calcium Carbonate, $CaCO_3$	53.61
Magnesium Carbonate, $MgCO_3$	7.17
Alkalis, Na_2O and K_2O	16.56
Ammonia, NH_3	0.04
Nitric Acid Anhydride, N_2O_5	5.71

A comparison of the soluble constituents given in this analysis with the soluble material extracted from the cave earth, as

shown in the preceding analyses, points forcibly to the probable origin of these salts in cavern earths.

It was found from analyses of many samples taken from Saltpeter Cave, Indiana, so as to cover practically the whole floor of the cavern from the opening to the end, that nitrates were distributed throughout the entire extent of the dry chamber, irrespective of distance from the entrance. Since bats do not go far inward from the entrance of caves, and since we find no organic matter in cave earth to indicate an animal origin for the nitrate contained therein, it is evident that we cannot regard the nitrates in cavern earths as originating from bat guano.

The conclusion reached from this investigation is that the nitrates in caves were brought in by water percolating through the soils above the caves and were deposited on the floors. Currents of air in and out of the caverns removed the water, and the various salts it previously held in solution were left as an inheritance to the cave earth. A cavern acts, therefore, merely as a receptacle for stopping a portion of the surface drainage. This accumulation of salts occurs only in caverns where the inflow of surface water does not exceed in amount the water removed by evaporation. In wet caves the soluble salts are washed onward with the water bearing them and so are not deposited.

Nitrates found under overhanging cliffs are of a similar origin. Water bearing dissolved nitrates percolates through the soil and finally oozes out at the surface. The water evaporates and leaves behind an incrustation of its soluble materials. The nitrates thus formed under overhanging cliffs remained permanently stored there, being securely protected from rain. They served, along with the nitrates found in the caves of Alabama and Georgia, as a source of saltpeter used by the South during the Civil War for the manufacture of gunpowder.

When vegetable matter is piled up and allowed to decay, an incrustation of potassium nitrate forms on the surface. The vegetable or organic nitrogen has been oxidized to nitric acid. The nitric acid combines with the potash of the plant to form potassium nitrate. The water evaporates from the pile and

leaves its load of nitrate behind as an incrustation on the surface, while water from the interior of the pile works gradually towards the surface to take the place of the water removed by evaporation. Thus the materials soluble in water are slowly brought to the surface and left as a deposit which may be removed mechanically. This is an old method of obtaining saltpeter from manure heaps, and it is even now used to a small extent in Europe. The occurrence of the nitrates in caves as an incrustation on the surface of the cavern earth shows that water has been removed by evaporation in much the same way as from the overhanging cliff and from the compost heap.

We always have nitrogenous matter scattered over the surface of the soil and this decaying vegetation furnishes continuously during its decay a small amount of nitric acid. All nitrates are soluble in water and so are sure to be found in the percolating water. If, then, the percolating water is intercepted and evaporated, the nitrate must be left behind. Nitrates should, therefore, occur in all caves and analyses of the cavern earths of a great number of caves in Indiana and Kentucky demonstrates that the occurrence of nitrates in cavern earths is general. No dry cavern earth was found which did not contain soluble salts of nitric acid, and these salts were distributed uniformly from the entrance to the end of the cavern.

WILLIAM H. HESS.

February 23, 1900.

THE CALCAREOUS CONCRETIONS OF KETTLE POINT, LAMBTON COUNTY, ONTARIO

It cannot be said that the mechanics of the concretionary process in sedimentary rocks is well understood. The well-known spherical concretions of Kettle Point, at the southern end of Lake Huron, appear to throw some light on the problem of the *mise en place* of thoroughly exotic material, aggregated by this slowly acting molecular attraction. The purpose of the present paper is to illustrate the mode of occurrence and to indicate some facts leading toward the interpretation of these singular bodies.

Logan has given us a concise description of the conditions at Kettle Point in the *Geology of Canada*, published in 1863.[1] Reference is also made to them by Rominger;[2] but in neither case was actual illustration employed nor description given of perhaps the most remarkable characteristic of the concretions.

About one half mile eastward of Kettle Point the highway from the town of Thedford decends sharply on a remarkably well preserved sea cliff of the formerly expanded Lake Huron, to the level of a gently sloping bench, cut in part in the drift, in part in the shales which underlie all this portion of Lambton county. At the Point itself the shales are seen to be wasting very rapidly on the face of a modern cliff from six to fourteen feet high and a few hundreds of yards in length. This condition is highly favorable to the exposure of the concretions, and one could hardly ask for more ideal sections for the study of structural details in the bed rock.

According to Logan these beds represent the equivalent of the Genesee Shale in New York state, which bears concretions of the same nature as those under consideration.[3] Rominger

[1] Pp. 387, 388.

[2] Rep. Geol. Sur. Michigan, Vol. III, 1873–1876, p. 67.

[3] Cf. Hall, Geology, Pt. IV, in the Nat. Hist. of New York, pp. 220 and 230.

put them in his "Black Shale" division of Michigan,[1] which C. E. Wright has called the "St. Clair Group."[2] The wide extent of these shales is further emphasized by their correlation with the important zone of the "Huron Shale" in Ohio.[3]

At the Ontario locality the rock is argillaceous throughout, of a dark brownish-gray to black color, which is partly due to

FIG. 1. General view of the shale at Kettle Point, showing jointing. Several concretions appear above the surface of the water.

the strong impregnation of bituminous matter, so abundant as to make the rock inflammable. Fossils are not rare; indeed, there is a very striking exhibition of large specimens of *Calamites inornatus*, and of other plants, lying prostrate in the shale. In addition to the calcareous concretions there is a great abundance of concretions of iron pyrites, which are, however, always small, generally lenticular, with the greatest diameter under three

[1] Op. cit., p. 67.

[2] Rep. Geol. Sur. Michigan, Vol. V, 1881–1893, Pt. II, p. 21 (ed. by Lane).

[3] NEWBERRY, Geology of Ohio, Vol. I, 1873, p. 154.

inches. The decomposition of the pyrites has led to the efflorescence of the usual sulphates of iron and alumina and of the hydrous oxalate of iron, humboldtite.

The shale is nearly horizontal, well laminated and very fissile, the flakes of the rock being readily split out and piled up on edge by the waves, which thus build a curious belt of jagged and

FIG. 2. Concretion and deformation of the shale.

shattered fragments on the bed rock. The only other notable structure in the interconcretionary spaces is the universal occurrence of two extremely perfect systems of vertical joints at right angles to each other (Fig. 1). These joints affect the shale only, and do not pass through the concretions anywhere, so far as I have had opportunity of observing the latter.

The most striking structure in the shales is, however, the local departure from the normal horizontal position of the parts of the beds in the immediate vicinity of the concretions. In every one of the dozen well-exposed concretions still in place the strata are plainly arched over the upper hemisphere and bend

under the lower, and show clearly the effect of deformation along the radii of the equator. In fact, the impression is at once given the observer that centrifugal force of nearly equal amount has been exerted along all radii of each sphere (Figs. 2, 3, and 5). A similar disturbance of the usual, nearly horizontal, attitude of the beds of this formation has been noted by New-

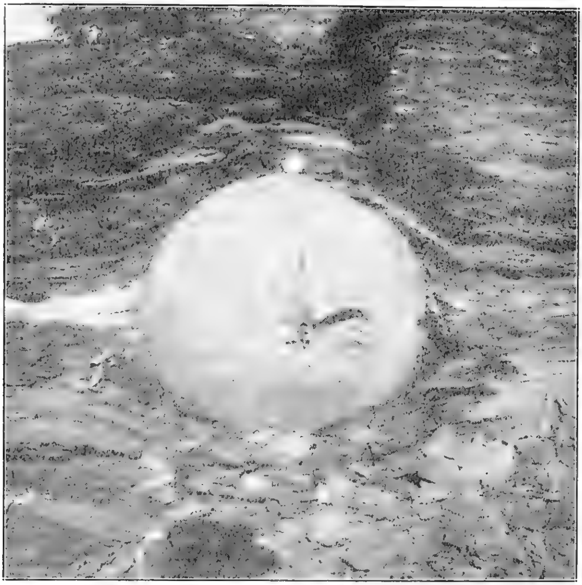


FIG. 3. Deformation of the shale about a medium-sized concretion.

berry at Worthington, Franklin county, Ohio,[1] and by Rominger in the "Black Shale" of Michigan.[2]

The concretions themselves are composed essentially of crystallized carbonate of lime, the crystals arranged radially and always in direct contact with one another. There is practically no argillaceous material in them, and in no observed case does the stratification of the country-rock run through the concretion. The shape is usually that of the almost perfect sphere (Fig. 4), though often this form is somewhat lost by the slight flattening

[1] Geology of Ohio, Vol. I, 1873, p. 155.

[2] Op. cit., p. 66.

of the concretion along the diameter perpendicular to the plane of stratification of the shale. True spheres and spheroids exhaust the list of observed forms. The average diameter is nearly two feet; the largest specimen now well exposed on the shore, a spheroid, has a polar diameter of a little more than three feet, an equatorial diameter of about three feet six inches

FIG. 4. General view of partially exposed concretions.

(Fig. 5); the smallest specimen may measure about one foot in diameter.

Large numbers of the concretions are being washed out of the much less resistant shales by the waves; their freeing from the matrix may be seen in all its stages (Fig. 4). But the number now remaining on the shore does not represent the total that could be counted were it not for the deplorable habit of the numerous visitors to the Point, who not only carry away the heavy specimens bodily, but break up others with the hope, destined to disappointment, of finding something at the core more

interesting than the interior of the already shattered "kettles." It is said that the concretions may be seen on the bottom in the very shallow water of the lake five or six miles from Kettle Point, and that specimens may be readily fished from the bottom as much as two miles from the shore, where they have been leached out by the erosive action of the larger waves.

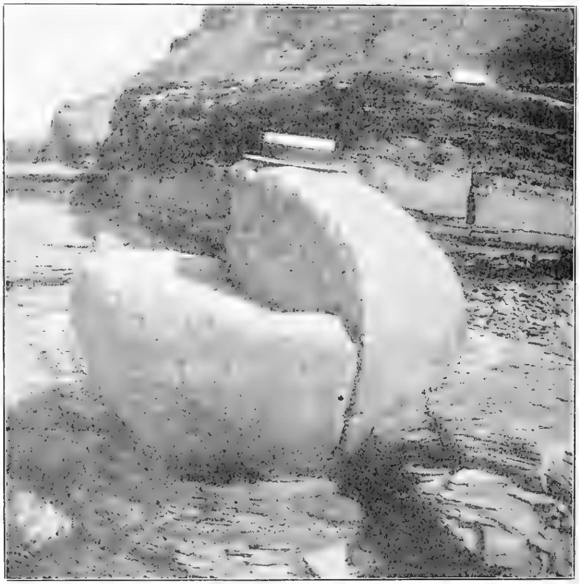


Fig. 5. Large concretion in place; the shale in its immediate vicinity exhibits slaty cleavage developed tangentially to the concretion.

Composing as they do such a comparatively large proportion of the rock, and occurring in similar profusion in the Upper Devonian of Michigan and Ohio, it is hardly just to say, in the words of Dana, that radial spherical concretions are "of inferior geological importance.[1]

A chemical analysis of one of the darker tinted brown concretions was made, and yielded the following percentage composition:

[1] Manual of Geology, 4th ed., p. 97.

$CaCO_3$	88.42%
$MgCO_3$	2.99
Fe_2O_3	0.71
Residue insoluble in HCl (SiO_2)	4.25
Hydrocarbons (and H_2O)	3.23
	99.60

FIG. 6. Looking down on the concretion of Fig. 5; fractured surface shows concentric structure, the radial arrangement of the crystals not conspicuous in the photograph.

The powder from which this analysis was made was previously dried at ordinary temperatures in a desiccator; any residual water was driven off at the low heat used to expel the hydrocarbons. The latter cannot then be said to have been exactly determined, but they probably do not total less than 3 per cent. The shales round about were found by Hunt to contain 12.4 per cent. of volatile matter, presumably hydrocarbons.[1] The appearance of the magnesian carbonate is to be correlated with the

[1] Chemical and Geological Essays, p. 179.

observation by Garwood that some of this substance must be present if a limestone concretion is to grow large, although his analyses show that more than 30 per cent. of that carbonate seems to prevent the concretionary process.[1]

In all cases the structure is typically radial throughout the concretion, except at the rather indefinite small core of massive crystallized lime carbonate, which can usually be seen at the center. I have found no organic center of concretion, and no center other than calcite in any specimen. The free ends of the radiating crystals present the characteristic cleavage-planes of calcite, and the curved surface of the sphere is otherwise indented only by the faint depressions where the latter was in contact with the layers of shale (Fig. 5). Lastly, there is often to be seen, in addition to the radial structure, a concentric banding in the split-open sphere, a layering that seems to be original and connected with varying conditions of growth (Fig. 6).

The most important problem in connection with these concretions doubtless adheres to the question as to how the strata came to be deformed on all sides of each spheroid. That very considerable mechanical energy has been expended in the process is evident, not only in the development of a dome over the upper hemisphere and of a cup holding the lower hemisphere, but also in that of a sort of slaty cleavage, which can sometimes be discerned in the shale adjacent to the equatorial zone (Fig. 5). What is the source of the energy?

One of the first explanations that suggested themselves to me consisted in referring the deformation of the beds to differential movements in the strata as these adjusted themselves to the loss of water, and to the ensuing consolidation of the original muds to shale. The concretion itself would not lose bulk in such a case, and the layers overlying would be supported at the upper pole of the spheroid, while there would be less and less of such support for the same strata along lines radiating from the pole in the horizontal plane, until a maximum of instability would be reached outside of the equatorial circle. Here there would

[1] Geol. Mag., 1891, p. 439.

be a maximum of collapse which means, in the end, a doming above the upper hemisphere. I have found that the same explanation had been brought forward by both Newberry[1] and by Rominger.[2] But it leaves out of account the structural cup, which holds the lower hemisphere, and which is just as well developed as the dome overhead (Fig. 3). Moreover, the existence of the concretion before the act of consolidation is not considered; yet we must believe that a theory of the deformation should be controlled by the recognition of the fact that many cubic feet of the shale must be displaced to permit of the growth of the larger concretions.[3] We know of no reactions by which replacement of argillaceous material by slow molecular interchange with carbonate of lime may take place, nor can we conceive of such large spherical and spheroidal cavities as those necessary for the segregation of the calcite as having antedated the segregation. The last supposition is particularly invalid, for, in any case, it would leave the radial structure unexplained.

The same objection may be made to the hypothesis that energy sufficient for the deformation of the strata might be forthcoming in the process of forming a pseudomorph of calcite after some other carbonate of greater density. Siderite does, indeed, occur in radially concretionary form in the Black Shale of Michigan.[4] But, while there might be an important increase of volume with the application of expansive energy analogous to that ensuing on the change from anhydrite to gypsum, we have still to account for the original displacement of the shale to make way for the siderite or other earlier carbonate itself. It may also be stated that the disturbance of the shale is visibly greater than is possible on a mere change of volume in the pseudomorphosing reaction.

There thus seems to be no escape from the conclusion that the crystallization of each concretion and the opening of the

[1] Op. cit., p. 155. [2] Op. cit., p. 66.

[3] NEWBERRY's largest concretion of the sort here described, and occurring under similar conditions, measures 10 feet in diameter, giving a volume of more than 500 cubic feet. Geology of Ohio, 1873, p. 155.

[4] Geol. Surv., Mich., Vol. III, 1873–1876, p. 67.

space in which it lies were contemporaneous processes ; the force used in deforming the beds must, in some way or other, be directly connected with the act of crystallization of the calcite.

The theory of this association that lies nearest to hand would explain it by deriving active mechanical energy from each crystal of calcite as it obtains new material at the outer extremity on the surface of the growing spheroid. This energy will, then, be that of a "live force," and will be directed centrifugally, forcing the shale to assume a position dependent on the relative rate of growth of the crystals in the bundle. If there be equal supply of carbonate in the surrounding matrix, the radiating crystals will grow at equal rates; the aggregate will be spherical, and the layers of shale will be forced to assume a corresponding position. A rate of supply more rapid along the plane of stratification than in a direction transverse to that plane would give a spheroid with a minimum diameter similarly transverse to the bedding, and a corresponding distortion of the shale mantle. In brief, this hypothesis calls for the production of a compressive force exerted on the surrounding medium by a growing crystal.

Bischof has said that "what we know of causes in the growth of crystals, we have learned in the chemical laboratory. This is our sole guide to a conception of crystallization in the mineral kingdom."[1] It must be confessed that the advocates of the theory of live force exerted by natural crystals have been few, and that almost all derive their whole argument from observations in the geological field, and not from those in the chemical laboratory. Unfortunately, too, many of the examples chosen by them cannot be taken as sure evidence of the exertion of such force by a crystal of a primary mineral, *i. e.*, one that has gathered its molecules, one by one, from a mother liquor, and that by virtue of the attraction of like molecule to like. And this is the case with our calcite molecule. With but few exceptions the argument for live force has been taken from the study

[1] Lehrbuch der chem. phys. Geologie, 2d ed., Band I, p. 140.

of minerals like wavellite, natrolite, and other zeolites, gypsum, serpentine, talc, and other hydrous secondary minerals; possibly pseudomorphs in every case, and if so, of less density, and occupying greater volume than the parent mineral. Such swelling substance can exert active centrifugal force. But we have already noted the fact that this cause of crowding in rock-masses cannot aid us greatly in explaining the Kettle Point concretions.

Basing his statement on such doubtful examples as those just mentioned, Bischof says: "Crystallization is a force which may be compared with that of the expansive force of heat."[2] On the other hand, he quotes Kopp, who opposed Duvernoy in his theory of a mechanical energy of crystallization by showing that a crystal of alum growing in a vessel never does so by accretion on the face upon which the crystal rests at the bottom of the vessel. Kopp thus concluded that the mechanical energy of crystallization must be very slight, if existent at all, in this case, of a crystal of exceptional rapidity of growth that cannot overcome its own trifling weight when immersed in the mother-liquor.[1]

At the same time, certain observers have noted instances where live force seems to have been exerted during growth by crystals or crystalline aggregates, which may not, or, indeed, certainly have not, been pseudomorphous derivatives from pre-existing minerals. De La Bèche, speaking of crystalline concretions of selenite and of iron pyrites, stated his belief that, in these cases, chemical affinity was strong enough "to overcome the attraction of cohesion" in the matrix.[2] Dana's example of rifting of quartzite by the growth of a limonitic deposit, and the wedging asunder of parts of a tourmaline crystal by the crystallization of quartz in which the tourmaline lies embedded, are too well known to need more than mention.[3] Similarly, Worthen's disjointed crinoids, the plates of which were gradually separated by the deposition of quartz between them, are cited by Dana as

[1] Bischof, Lehrbuch, Band I, p. 134.

[2] Researches in Theoretical Geology, 1834, p. 91.

[3] Manual of Geology, 4th ed., p. 138.

proving displacement by the force of crystallization. More recently, Professor Shaler has appealed to the hypothesis of tensional force to explain the opening of certain vein-fissures, the latter not being explicable by the usually accepted idea of open fissures.[1]

In certain of these cases, it may be agreed that the mechanical force expended seems to have been applied *pari passu* with the process of crystallization; so far as I have been able to find direct statement of the mode of application, each writer signifies his belief that the crystal itself did the work of rifting or of crowding together. We have seen that what little experimentation has already been carried out so far, leaves this interpretation decidedly weakened. The question arises as to whether the energy is set free in the act of crystallization in ways other than in the form of a push exerted by the growing crystal. An answer has suggested itself to me, and I shall briefly outline it, without, I trust, seeming to imply that the idea is anything more than a somewhat highly specialized working hypothesis.

In the Kettle Point shales, saturation of the underground waters by both free and combined carbon dioxide is not hard to imagine. An abundant supply of the gas could be found in the decomposition of the carbonaceous matter in the shales;[2] the monocarbonate of lime is supplied in all necessary quantity from the calcareous bands in the shale and from the underlying Devonian limestones.

Suppose now that a small fragment of carbonate of lime, organic or other, is enclosed in a rock, with a capillary film between mineral and rock. This fragment will act as the immediate stimulus to the decomposition of any sufficiently saturated

[1] Bull. Geol. Soc. Amer., 1899, Vol. X, p. 259.

[2] The analysis of the gas given off from the "east crater" among the Mississippi mud-lumps of 1871 gave the following result: CO_2 9.41 per cent., marsh gas 86.20 per cent., N 4.39 per cent. HILGARD, Amer. Jour. Science, 1871, (1) p. 426. While the percentage of CO_2 is high, we may still regard this analysis as representative of the normal gases given off in the decomposition of vegetable matter buried in mud.

bicarbonated water that may be in contact with it.[1] Monocarbonate is precipitated about the fragment and a double biproduct is formed of water less strongly charged with the bicarbonate than before, and of carbon dioxide, which may be kept in solution in the water. The volume of new monocarbonate, together with that of the biproducts, is greater than that of the original bicarbonate;[2] expansion is necessary. The result would be the development of pressure directed centrifugally with respect to the fragment. This pressure will be the sum of all those minor pressures produced by the single decompositions of bicarbonated water entering by each of a million passages to the point where the solid carbonate is reached. The integrated force may have great efficiency. It would tend to expel the water from the surrounding capillary passages. If the expulsion kept pace with the crystallization, the space between the mineral and the adjacent rock-substance would soon be completely closed and crystallization and growth of the concretion would cease.

But the experiments of Jamin[3] have proved that equilibrium may exist between two unequal pressures affecting the ends of a capillary tube, provided a column of liquid occupying the tube be interrupted by bubbles of air. The presence of the latter excites capillary attraction which is so strong as to take up

[1] It is a familiar fact that crystallization can often be brought about, when not produced by other means, by introducing a crystal of the substance, the crystallizing of which is desired. Further, the mass of substance dissolved in water and coming in contact with a mineral, is very small compared with that of the mineral; if there ensue a chemical reaction, it is the large mass of the mineral that regulates the laws of affinity. Thus, solid carbonate of barium decomposes dissolved bicarbonate of calcium, and solid calcium carbonate decomposes dissolved barium carbonate; à fortiori, solid calcium carbonate will decompose dissolved calcium carbonate, i. e., the bicarbonate. Cf. Bischof, Lehrbuch, Band I, p. 114.

[2] That expansion will result has unfortunately not yet been proved by experiment in the case of $CaCO_3$, but it is inferred from the law that expansion of volume follows on the separation of salts from their solutions in those instances where increased pressure aids solubility. Engel has determined that the solubility of carbonate of lime in carbonated water increases very rapidly with an increase of pressure, e. g., doubling with a rise of pressure from one to six atmospheres. Comptes Rendus, Vol. CI, p. 949.

[3] Comptes Rendus, Tome L, 1860, pp. 172 and 311.

several atmospheres of pressure applied at one end of the tube. The force so expended is represented in the compression of the air bubbles and in changing the form of the air menisci; surface tension is thus overcome. The movement of the bubbles progressively decreases in the direction of the greater pressure until one is reached which is not disturbed at all so long as the pressures remain constant. The bubbles act like so many buffers. Any capillary tube filled with water interrupted by any insoluble gas or liquid possessing a lower surface tension than water, will exhibit the same phenomenon. Let us return to our incipient concretion.

Round about the grain of carbonate, there is an infinite network of capillary passages largely occupied by water in the early history of the rock. Along with the water, are gaseous and liquid hydrocarbons that are slowly being evolved by the decomposition of organic matter. The distribution of the hydrocarbons will be such as to bring about capillary attraction, and therewith the possibility of differential pressures within the water-mass, though it be in equilibrium throughout. Thus at the capillary film separating lime fragment and argillaceous wall, we may have great outward pressure unaccompanied by the expulsion of water along the channels leading from the country rock to the fragment. The latter is girt about with a mesh of capillary passages enormously resistant to movement of the contained liquids, and permitting of greater hydrostatic pressure within than without. The form of the mesh itself may change however, without interfering with its function as a buffer. The centrifugal pressure will then be occupied in deforming the rock, and it may conceivably be aided by the expansive energy of the freed CO_2. Fresh supplies of bicarbonated water will slowly diffuse into the capillary space between concretion and rock and further the displacing process. The solid carbonate as it were, keeps pulling a trigger that sets off the reaction of decomposition, which does not occur at a distance from the fragment. The biproduct cannot escape as fast as formed and the country-rock must be crowded away. The deformation is then, analogous

to that produced by the freezing of water in a closed vessel, being caused by a change of volume, and not by the thrust of the crystals as such.

Much of this general scheme can be applied with certainty to the Kettle Point concretions. Bicarbonated water unquestionably was the source of the calcite substance; the decomposition was induced locally at the call of pre-existent carbonate, and the double biproduct described must have resulted. Since the joints in the shale are undoubtedly due to desiccation, it is but fair to suppose that the concretions antedate them. The presence of hydrocarbons during the concretionary growth is likewise reasonable. The resulting surface tension in this deep-lying water would thus bring about capillary action which was especially powerful on account of the extremely small size of the channels through which water could migrate in the shale.

The shape of the growing concretions will depend primarily on the resistances offered to displacement by the shale, and, perhaps, secondarily, to the rate of supply of bicarbonate. From the homogeneous character of the shale, we are led to believe that both of these actions will be nearly equal in all directions throughout the rock, with, however, a slight advantage in power of resistance to be ascribed to the direction at right angles to the plane of stratification. The resulting form of the concretions would, in consequence, be that of a sphere or of a spheroid. The calcite crystals will assume radial positions according to a law of crystal growth that does not concern us here; they will grow outward into the shallow space offered by the outward thrust until the biproduct has slowly diffused through the argillaceous wall.

In conclusion, then, it may be stated that the concretions were formed in place within the shale, that they antedate the period of joint development and final consolidation of the surrounding rock, that the local deformation of the shale accompanied the process of crystallization, and that the energy of the deformation appears to have been derived from the change of volume induced by the breaking up of the bicarbonate into

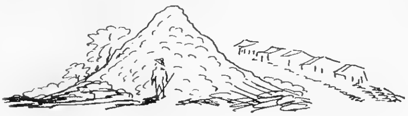
monocarbonate and fluid biproduct. The introduction of capillarity to explain the existence of differential pressures in the rock-mass cannot be regarded as other than hypothetical. It is hoped that the suggestion may lead to fruitful experimentation; for it is doubtless to the experimental geologist and to the physical chemist that we must finally appeal in determining the source of mechanical energy in deep-seated chemical reactions. The hypothesis should, of course, also be tested by reference to the conditions at other localities where deformation in sedimentary rocks has been produced during the growth of concretions, whether composed of calcite or of other material.

REGINALD A. DALY.

ANTS AS GEOLOGIC AGENTS IN THE TROPICS

A FEW years ago in treating the subject of the decomposition of rocks in Brazil I spoke of ants as geologic agents worthy of consideration[1] My claims for these humble workers were apparently accepted under protest. With this protest I confess I have much sympathy, for if I had not seen with my own eyes so much of these ants and their remarkable deeds I never should have believed half the stories told of them.

Last summer while visiting Brazil again I made a few notes upon the ant-hills in the State of Minas Geraes, and took a photograph showing the kinds of hills so common in certain parts of that state. I went into the interior at one place by the Bahia and Minas railway, which, starting from the coast near Caravellas in the State of Bahia, runs to Theophilo Ottoni (formerly called Philadelphia) in the State of Minas, a distance of 376 kilometers. The first 160 kilometers of the road is over campos of hard baked Cretaceous clays with only patches of forest here and there. Beyond this the rocks are crystalline, mostly gabbros and gneisses, up nearly to the end of the line where the rocks are old metamorphic mica schists, itacolumites, etc., all deeply decomposed. Shortly after leaving the Cretaceous area my attention was attracted by the big ant-hills in the forests. These mounds are from three to fourteen feet high and from ten to thirty feet across at the base. The new ones are steeply conical and the old ones are rounded or flattened down by the weather. In many places these mounds are so close together that their bases touch each other.



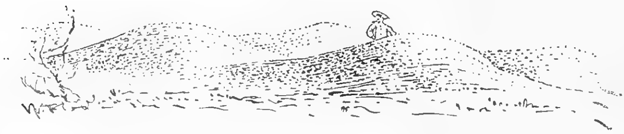
An ant-hill at Urucú station, Bahia and Minas railway.

About Urucú station (k. 226) the ant-hills are so thick that the country looks like a field of gigantic potato hills.

[1] Decomposition of rocks in Brazil, by J. C. BRANNER: Bul. Geol. Soc. Amer., 1896, VII, 295–300.

In the vicinity of the city of Theophilo Ottoni there are several old fields apparently abandoned to the ants. The accompanying plate is from a photograph taken on the slope of the hills west of the railway station at this city. The mounds here are all low and rounded as if they were old.

I regret that this picture does not give a better idea of the size and abundance of the ant-hills; unfortunately it was taken when the sun was almost directly overhead, and the view is up the slope and along the side of the hill. Before the photograph was made the man in foreground was sent behind the hill at the foot of which he sits, but though he was over six feet high I could only see the top of his hat. The black lumps shown are hard masses weathered from the large mounds.



Ant-hills in an old field on the Rio Mucury, State of Minas Geraes, Brazil.

In the city of Theophilo Ottoni the streets are cut down in many places through the rock decayed in places. In some of the fresh cuts I observed the holes made by ants penetrating the ground in one place to a depth of ten feet, in another to a depth of thirteen feet, below the surface of the ground; many others were seen at a depth of six, seven and eight feet below the surface.

It goes without saying that the ants do not bore into the hard undecayed rocks, but it seems reasonable to suppose that the opening up of the ground by their long and ramifying underground passages hastens decay, and that the working over of the soil must contribute more or less to the same end.

The impression one gets from the work of the ants along the line of the Bahia and Minas railway — and for that matter in any other part of the tropics — is that they are vastly more important as geologic agents than the earthworms of temperate regions.

Since the publication of my paper upon the decomposition of rocks in Brazil, in which several writers are quoted upon the work

of ants in that country, I have found a few interesting notes upon the subject some of which I quote here.

Speaking of the ants in the River Plate country Sir Woodbine Parish refers to "Corrientes and Paraguay, where whole plains are covered with their dome-like and conical edifices, rising five and six feet in height."[1]

Ant-hills on the hills west of the city of Theophilo Ottoni, State of Minas Geraes, Brazil.

The Robertsons mention ants' nests among the palms near Assuncion, Paraguay, as "thousands of conic masses of earth, to the height of eight and ten feet, and having a base of nearly five in diameter."[2]

Referring to the injury done to crops by the saúba ants the president of the Imperial Instituto Fluminense de Agricultura says: "Among the obstacles with which planters have to contend . . . . there stands perhaps in the front ranks the destructive force represented by the saúba."[3] JOHN C. BRANNER.

[1] Buenos Ayres and the provinces of the Rio de la Plata, by SIR WOODBINE PARISH: 2d ed., p. 252. London, 1852.

[2] Letters on Paraguay, by J. P. and W. P. ROBERTSON, Vol. I, 270–274. London, 1838.

[3] Henrique de Paulo Mascarenhas in the Revista Agricola do Imperial Instituto, December 1883, XVI, 215.

VARIATIONS OF GLACIERS. V.[1]

THE following is a summary of the fourth annual report of the International Committee on Glaciers:[2]

RECORD OF GLACIERS FOR 1898

Swiss Alps.—Of the seventy glaciers which were measured in 1898, twelve are advancing, fifty-five retreating and the others doubtful.[3]

Eastern Alps.—The variations reported last year on the Gliederferner and Vernagtferner are confirmed by further measures. The swelling of these glaciers continues to advance down the valley and to carry with it an increased velocity of motion. When it reaches the end of the glacier there will be an advance of the ice. The majority of the glaciers are retreating, though a few of them are advancing. On the whole the tendency to retreat seems to be increasing.[4]

Italian Alps.—The glaciers of Mount Disgrazia, and those of the south side of the Bernina group are all retreating at the rate of several meters a year.[5]

Scandinavian Alps.—The glaciers of Sweden so far as observed show insignificant changes. They are probably stationary. The velocity of the Stuorajekna near its end was found to be about twice as rapid in summer as the annual average.[6]

Polar Regions.—In 1898, the large glacier between Mt. Hedgehog and South Cape, Spitzbergen, was found to project several kilometers into the sea. This glacier is not shown on former maps, and it is therefore possible that it has recently made a great advance.[7]

[1] The first four articles of this series appeared in this JOURNAL, Vol. III, pp. 278–288; Vol. V, pp. 378–383; Vol. VI, pp. 473–476, and Vol. VII, pp. 217–225.

[2] Archives des Sciences Phys. et Nat., Vol. VIII, pp. 85–115.

[3] Report of Professor Forel.

[4] Report of Professor Finsterwalder.

[5] Report of Professor Marinelli.

[6] Report of Dr. Svenonius.

[7] Report of Dr. Nathorst.

Greenland.—Steenstrup and Drygalski have both concluded from their observations, that the great cold of winter greatly reduces the velocity of motion of the smaller glaciers, but that the large glaciers, nourished by the inland ice, are very little affected by the seasons. Drygalski has found a velocity of twenty meters per day in the great Karajak glacier. The Asakak glacier on the Nugsuak Peninsula has been observed at intervals for fifty years. It retreated nearly a kilometer between 1849 and 1879, and has since then advanced even more. The Sermiarsut glacier no longer reaches tide water as it formerly did, but the other small glaciers of this region show no marked changes. The Blase Dale glaciers on the island of Disco, have continued to retreat since the visit of Professor Chamberlin in 1894.[1]

Canada.—The Upper Bow glacier is slowly advancing, but it has not yet reached the extent indicated by former moraines. Freshfield glacier was advancing in 1897, plowing up the débris in front. Stutfield glacier has been covered with débris by great avalanches, and the melting has thus been retarded. As a result the ice is advancing down the valley and is now in the midst of the forest. It is at least a half mile beyond its former limits. The Illecellewaet glacier has retreated 100 to 150 meters since 1888, and probably 200 meters within the present century.

Himalaya.—The Tarsching glacier apparently retreated between 1850 and 1870, at which latter date it was advancing. It seems to be advancing at present and may block up the valley above it, and cause inundations as it has done before.

Africa.—Dr. Hans Meyer visited the cone of Kibo, the highest point of Kilimanjaro, in 1898 and described the extent of its glaciers. The summit is about 6000 meters high, and the ice streams down on all sides. On the northern and eastern sides the winds are dry, and the glaciers only descend a few hundred meters; whereas on the southern and southwestern sides, the winds are moist and one glacier descends as much as 2000 meters from the summit. There has been a distinct retreat since Dr. Meyer's visit in 1889. Dr. Meyer has also discovered

[1] Report of Dr. Steenstrup.

traces of a glacial period on Kilimanjaro, which confirms similar observations of Gregory further north on Kenia.[1]

Caucasus.—The glaciers in the neighborhood of Mt. Elbruz are retreating at the rate of eight or ten meters a year, with the exception of the Adyl, which has advanced six or seven meters between 1897 and 1898.[2]

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1899[3]

Montana.—Sperry glacier, discovered a few years ago, is retreating—(*L. B. Sperry*).

Mt. Adams, Wash.—This volcanic peak, like the others of this region, has a number of glaciers streaming down its sides. The White Salmon and the Mazama, respectively, on the southwestern and southern slopes of the mountain, are broad and comparatively short masses of ice. Each divides into two tongues. The White Salmon is largely covered with débris, while the surface of the Mazama is clean to its ends, though it has a large lateral moraine. The causes of these differences do not appear.

On the eastern side of the mountain are the Klickitat and Rusk glaciers, both of which lie in deep canyons. They are two or three miles long, the latter being the shorter. The Klickitat is connected with the ice-cap of the mountain through three couloirs, and is also nourished by ice avalanches which fall down the great precipice which characterizes the eastern side of the mountain. The Rusk derives all its material from avalanches. Neither are free of moraines. The other slopes of the mountain are not cut into ravines and the glaciers on the northern side, probably four in number, are not very distinctly separated from each other; they are also thoroughly covered with débris, so that they could not be readily distinguished from a distance.

The Klickitat glacier was retreating in 1890 (*C. E. Rusk*), but no information is available regarding the variations of the others.[4]

[1] Report of Mr. Norman Collie. [2] Report of Mr. Mouchketow.

[3] A synopsis of his report will appear in the Fifth Annual Report of the International Committee. The report on the glaciers of the United States for 1898 was given in this JOURNAL, Vol. VII, pp. 221–225.

[4] The account of these glaciers is taken from descriptions by Professor W. D. Lyman and Mr. C. E. Rusk in the Mazama Magazine, Vol. I, and from a special communication from Mr. Rusk.

Mt. St. Helens.—A glacier on the north side of this mountain was advancing and destroying trees in 1895 (*C. E. Rusk*).

Mount Ranier.—The Nisqually glacier has retreated not less than 100 meters since 1894 (*E. T. Allen*).

Alaska.—Last summer, Mr. E. H. Harrington of New York, invited a number of scientific men to accompany him on a voyage along the Alaskan coast. The full results of the expedition are to be published by the Washington Academy of Sciences.

Twenty-two tide-water glaciers were examined and marks left near many of them by which future changes may be measured.

Photographs and observations made by several members of the expedition show that all the glaciers visited are now retreating except the Crillon glacier on the west side of Mt. Crillon. This glacier does not reach tide-water; it is advancing against the forest and destroying the trees.

Prince William Sound.—Mr. Gannett mapped the glaciers and found that they are all retreating. The Harvard and Yale glaciers have retreated nine miles in a century.[1]

The Columbia glacier is now retreating, but the disturbed ground in front of it shows that it has recently advanced. The young trees growing on this disturbed surface place the date of the advance eight or nine years ago. The Muir glacier made an advance about the same time (*G. K. Gilbert*).

Glacier Bay.—All the glaciers seem to be retreating. In 1879, the three glaciers at the head of the bay were united and three or four miles in advance of their present positions. The Charpentier and Hugh Miller also formed one glacier and extended two or three miles further than they now do. Rendu and Carroll glaciers have suffered decided recessions since 1896 (*John Muir*).

A comparison of photographs taken by Mr. Gilbert in 1899, with others taken by the author in 1892, shows that in that

[1] The Harriman Alaska Expedition, by Henry Gannett, Nat. Geog. Mag., 1899, Vol. X, pp. 507–512; and Bull. Amer. Geograph. Soc., 1899, Vol. XXXI, pp. 345–355.

interval, the Grand Pacific glacier has retreated 500 to 600 yards; and the Hugh Miller 300 to 400 yards; the tide-water end of the Charpentier has receded nearly a mile and the Alpine end is now a mass of disconnected dead ice.

The records of Muir glacier are increasing. We know approximately its extent in 1880 from Professor Muir; and in 1886 from photographs by Professor Wright; and accurately in 1890 and 1892 from surveys by the author; pretty well in 1894 from photographs by La Roche of Seattle, and accurately again in 1899 from surveys by Mr. Gannett. With the exception of a slight advance between 1890 and 1892 the glacier has been pretty steadily receding. At present its extreme point in the middle of the inlet is not much behind its position eight or ten years ago, but the sides have receded fully half a mile. Morse glacier, a tributary on the west, became entirely separated from Muir glacier between 1892 and 1894 and continues to get shorter. Dirt glacier will probably also be an independent glacier before long.

Mr. Otto J. Klotz, of the Canadian Topographical Survey, concludes from a comparison of Vancouver's description of Taylor Bay with its present extent, that the Brady glacier in 1794 was at least five miles shorter than in 1893, when the Canadian survey was made, and that at the earlier date the glacier ended in tide-water. At present its end rests on gravels and does not quite reach the sea. These gravels must then have been laid down in the interval. He also concludes from Vancouver's descriptions and that of Sir George Simpson regarding Stephens' passage in 1841, that all the glaciers south of Fairweather Range have been steadily retreating in the last century. This, however, does not preclude temporary advances of individual glaciers, such as the Patterson, which, according to the *Pacific Coast Pilot* of 1891, was advancing and destroying trees at that time. The Le Conte glacier is at the head of a fiord about six miles long, and has retreated about half a mile between 1887, when the United States Coast and Geodetic Survey chart was made, and 1893, the time of the Canadian survey. A

description of this region by Vancouver does not give any reference to this fiord. It is therefore probable that it was entirely filled with ice a hundred years ago, which would indicate a retreat of Le Conte glacier of six miles in a century.[1]

HARRY FIELDING REID.

GEOLOGICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
March 22, 1900.

[1] Notes on Glaciers of Southeastern Alaska and Adjoining Territory, by OTTO J. KLOTZ: Geog. Jour., 1899, Vol. XIV, pp. 523–534.

STUDIES FOR STUDENTS

THE PROPERTIES OF BUILDING STONES AND METHODS OF DETERMINING THEIR VALUE[1]

I. NECESSARY CONSIDERATIONS IN THE SELECTION OF STONE

QUARRY observations, building inspection, and laboratory examination of building stone are conducted to satisfy the individual and the public that the stone under consideration possesses a color which will remain permanent and inherent qualities which give it a capacity to effectually withstand the atmospheric and other conditions to which it will be subject when in use.

It is my purpose in this number to discuss: (1) Color; (2) the inherent qualities of stone which limit its capacity to withstand atmospheric and other conditions; and (3) the atmospheric and other conditions to which building stone may be subject. In a following number quarry observations, building inspection, and the laboratory examination of building stone will be considered.

[1] This subject has been discussed very freely by geologists, architects, and engineers for twenty or twenty-five years. Many of the ideas expressed in this and the following number are a repetition of the conclusions reached by men who have previously entered this field of discussion. However, it would be a very uncertain task to endeavor to give any one credit for first enunciating the principles herein stated.

The following is a list of the more important American publications which treat, more or less fully, the subject considered in these studies, and to which the reader is referred: The Experimental Tests of Building Stones, by ROBERT G. HATFIELD, Trans. Am. Soc. of Civil Engineers, Vol. XLVIII, pp. 145–151, 1872; Report on the Building Stones of the United States, Appendix of the Annual Report of the Chief of Engineers, U. S. A., 1875; Notes on Building Stones, by HIRAM A. CUTTING, Vermont, 1880; Building Stones of Colorado, by REGIS CHAUVENET, Report of the Colorado School of Mines, pp. 1–16, 1884; The Building Stones of Minnesota, by N. H. WINCHELL, Report of the Geological and Natural History Survey of Minnesota, Vol. I, pp. 142–203, 1884; Special Report on Petroleum, Coke, and Building Stone, The Tenth Census of the United States, 1884; Report on Building Stones, by JAMES HALL, Thirty-ninth Annual Report of the New York State Museum of Natural History,

Color.—The predominant colors of stone are white, gray, brown, red, yellow, buff, blue, black, and green.[1] Ordinarily the color of a rock is not simple but composite, being a resultant of the different colors of the constituent minerals.

The sedimentary rocks on account of the simplicity of their mineral composition approach more nearly to what is known as a simple color than do the igneous. The shades of brown, buff, yellow, red, gray, or blue imparted by a sedimentary rock are mainly attributable to the presence of the oxide, carbonate, or sulphide of iron, bitumen, and carbonaceous matter in the form of graphite. The white and gray colors of marble, limestone, and dolomite may be attributed to the calcite or dolomite of which the rock may be composed.

pp. 186–224, 1886; The Collection of Building and Ornamental Stones in the United States National Museum, by GEORGE P. MERRILL, Smithsonian Report, Part II, pp. 277–520 1886; Igneous Rocks, by J. F. WILLIAMS, Annual Report of the Arkansas Geological Survey, Vol. II, 1890; Building Stone in the State of New York, by JOHN C. SMOCK, Bulletin of the New York Museum of Natural History, Vol. III, No. 10, 1890; Marbles and Other Limestones, by T. C. HOPKINS, Report of the Arkansas Geological Survey, Vol. IV, 1890; Stones for Building and Decoration, by GEORGE P. MERRILL, John Wiley and Sons, 1891 and 1898; The Onyx Marbles, by GEORGE P. MERRILL, Report of the United States National Museum, pp. 539–585, 1893; Marbles of Georgia, by S. W. MCCALLIE, Bulletin No. 1 of the Geological Survey of Georgia, 1894; Notes upon Testing Building Stones, by T. LYNNWOOD GARRISON, Trans. Am. Soc. of Civil Engineers, Vol. XXXII, pp. 87–98, 1894; The Relative Effect of Frost and the Sulphate of Soda Efflorescence Tests on Building Stones, by LEA MCI. LUQUER, Trans. Am. Soc. of Civil Engineers, Vol. XXXIII, pp. 235–256, 1895; Report on Tests of Metals, etc., at Watertown Arsenal; Reports of the United States War Department, pp. 322, 323, 1895; also 1890 and 1894; The Building Materials of Pennsylvania; I, Brownstones, by T. C. HOPKINS, Appendix to the Annual Report of Pennsylvania State College for 1896; The Bedford Oolitic Limestones of Indiana, by T. C. HOPKINS and C. E. SIEBENTHAL, Twenty-first Annual Report of the Department of Geology and Natural Resources of Indiana, pp. 290–427, 1896; Properties and Tests of Building Stones, by H. F. BAIN, Eighth Annual Report of the Iowa Geological Survey, 1898; The Building and Decorative Stones of Maryland, by GEORGE P. MERRILL and EDWARD B. MATHEWS, Report of the Maryland Geological Survey, Vol. II, pp. 47–237, 1898; The Building and Ornamental Stones of Wisconsin, by E. R. BUCKLEY, Wisconsin Geological and Natural History Survey, Bulletin No. IV, 1898. Reference should also be made to the Engineering, Mining, Architectural, Building, Stone, and similar technical journals in which this subject is discussed in current articles.

[1] Speaking from the purely scientific standpoint all of these are not colors, although they are referred to as such in this paper.

When iron occurs in sedimentary rocks, more especially sandstone, it often serves as a cement by which the original particles are bound together. However, it may also occur as an original constituent in the shape of finely disseminated particles. Carbonaceous matter in the form of graphite, or bitumen in the shape of petroleum occurs mainly in limestone and marble, often contributing to these rocks the blue or grayish-blue colors so commonly observed.

Among sedimentary rocks the color varies widely, not only in the same quarry, but often in the same bed. Certain beds in a quarry may have a delightfully cheerful, uniform color, while those immediately above or below may be dull and somber. In many places the coloring matter is distributed through the beds in regular bands, but occasionally it is very curiously disseminated, forming irregular, fantastic figures. White sandstone is often colored with large and small brown spots, while brown sandstone is sometimes similarly variegated with white spots. All stone which is distinctly mottled or irregularly colored is known as "variegated stone."

The color of an igneous rock is usually composite, as a result of the blending of the distinct colors of the mineral particles. The color, however, does not depend entirely upon the colors of the individual minerals, but in part upon the size and distribution of the constituent particles. In some instances the individual grains are sufficiently large to retain their own color, and the stone is spoken of as being mottled.

With respect to color, granites are ordinarily classified as red and gray. Whether a granite belongs to the first or second class will depend mainly upon the red or white color of the feldspar. Many granites contain both red and white feldspar, but as long as the red variety is sufficiently abundant to impart a reddish tone to the rock, it is called red granite. The most brilliant red granites have a preponderance of medium-sized, deep red feldspar individuals. As the feldspar individuals become finer grained and less deeply colored and biotite, amphibole, or pyroxene becomes more abundant, the color is subdued producing dull red effects.

The gray granites are dark or light colored, depending upon the size of the individual grains and the amount and kind of the ferro-magnesian minerals present. The light-colored granites have a preponderance of white feldspar and quartz, with muscovite as the main ferro-magnesian mineral. The dark gray granites contain less feldspar and quartz, and a greater abundance of biotite, hornblende, pyroxene.

Other igneous rocks such as "labradorite granite" with its blue iridescent color, and rhyolite with its almost black color, are commonly met with. The iridescent color of the former is imparted by the abundant porphyritic individuals of labradorite, of which the rock is largely composed. The black color of the latter is due largely to its semi-crystalline groundmass, which often abounds in fine crystals of hornblende. Serpentine is an abundant constituent of some rocks, and as such imparts to them a green color. The dull greenish-gray color so conspicuous among the basic rocks such as gabbro, diorite, and diabase, is imparted mainly by the minerals of the hornblende, pyroxene, amphibole, chlorite, and epidote groups.

The color of a rock when freshly quarried may be almost perfectly white but a few years, or perhaps months, of exposure to the weather may change the color to a buff, or streak it with irregular patches of brown. Such color changes result chiefly from the presence of easily decomposed minerals within the stone itself. The yellow color of many limestones is due to the presence of finely disseminated iron, as the carbonate or sulphide, which has altered to the oxide. If a stone contains either of these the color will change as a natural consequence of exposure to the atmosphere. The oxides of iron are more stable compounds than the sulphide or carbonate, and very seldom cause a change in color.

A change in the color of the stone in a wall may be due to impurities in the mortar, cement, brick, or water used in the construction and not to the presence of easily decomposed minerals in the stone. The committee appointed to investigate the cause of the brown stains on the walls of the State Historical Library

Building at Madison, Wis., reported that the Bedford limestone, out of which the building is constructed, was practically free from ferrous iron, and that the cause of the iron staining was attributable mainly to the cement used in the back wall. This is probably a frequent cause of discoloration, on account of which good stone has been condemned. A common method of preventing the ferrous iron in the brick or mortar of the back wall from coming to the surface, is to use a coat of asphalt between this and the stone facing. A better precaution would be to select lime, cement, and brick from which ferrous lime is known to be absent.

A change of color through the decomposition of iron sulphide and carbonate is manifest mainly among the light colored rocks. The blue or gray limestones and dolomites are often discolored by spots or irregular efflorescent patches of calcium or magnesium sulphate, which appear as a white precipitate on the surface. Their presence at this place is attributed to interstitial water, which comes to the surface bearing soluble salts of magnesium and calcium, mainly the former. Dark colored rocks such as brown sandstone do not discolor, but occasionally they take on a lighter tint after long exposure to the weather. This comes about through the loss of iron oxide which is washed off from the surface by the rains. Decoloration, however, takes place so slowly that it is not an important consideration.

Very often, through long exposure in the quarry a rock, such as the blue limestone of the Trenton formation, is partly or entirely altered in color to a buff. Near the surface, beds may be found that have been completely altered, while deeper in the quarry one passes from those that are partly altered to those that are unchanged. The alteration commences along the joints and gradually passes toward the center of the blocks.

The manner in which a stone is dressed sometimes affects the permanency of its color. A rough dressed stone furnishes a multitude of places in which dust and dirt may lodge, while one which is smooth dressed is free from such places. For this reason there is less danger of the original color being obscured in a smooth

than in a rough dressed stone. On the other hand a smooth dressed stone emphasizes blemishes in color which may be obscured by rough dressing. These color blemishes may be more unsightly than the "tan" of smut and dust, in which case it would be preferable to rough dress the stone.

Fashion, dominated by color, influences the exploitation and the market value of different stones. Until a few years ago brownstone was preferred, both for business blocks and residences, but people became weary of gazing at long rows of somber colored buildings and the fashion changed to light colored stone. At the present time immense quantities of light colored stone are being used, but the fashion will change again in a few years and the pendulum will swing back to brownstone. A judicious use of both would serve to relieve the monotony of long rows of brownstone buildings and of the dazzling glare of white limestone and marble. It is to be hoped that the time will come when the use of neither light nor dark stone will be supreme.

In the large cities, other things being equal, the permanence of color ought to be a factor worthy of consideration in the erection of residences and tenement houses. However, in the construction of business blocks it scarcely warrants serious attention. A white limestone or marble structure erected in the midst of a business portion of a large city soon loses its original color, becoming gray and dingy from the omnipresent smoke and dirt. If the limestone is bituminous and contains a small amount of oil, all the dust and smoke which chances to fall upon it will be retained. The walls of most of the buildings in the business section of our large cities eventually become so begrimed with smoke and dust that it is barely possible to tell whether the stone was originally dark or light colored. One needs to familiarize himself with the characteristic brown and gray shades of stone which have been steeped for years in a smoke and dust laden atmosphere, in order to be able to determine the original colors.

On the whole the dark colored stone shows much less than does the light the effects of smoke and dust. Nevertheless the

only consideration in the selection of stone to be used in the business portion of a large city should be strength and durability.

In the suburban and resident parts of a city and in rural districts, where smoke and dust are trifling matters, the original color will not suffer seriously from external causes alone. In these places beauty is one of the chief ends of architecture, and a judicious scattering of light and dark colored stone buildings adds very materially not only to the appearance of the street as a whole, but also to the beauty of the dwellings individually.

When used for interior decorations, a stone does not suffer materially from atmospheric agencies, and the color will ordinarily remain permanent. The selection of stone for these uses, then, becomes largely a question of taste. A color which harmonizes with the surroundings or matches the other work, is generally considered most appropriate. In the flooring or steps, the capacity which the stone has to withstand abrasion without becoming unduly slippery, and not color, should be the controlling factor.

For monumental purposes the taste of the purchaser is again the main, controlling factor in the color selected. The stones used for monuments are mainly igneous and metamorphic (granite and marble), and as such contain few minerals which will result in discoloration. If pyrite or marcasite are constituents of the stone there will be danger of discoloration. However, the fact that most of the water which falls upon a granite monument is shed by its polished surface, lessens the danger of discoloration, by preventing decomposition.

In the more common uses to which stone is put, such as road making, sidewalks, retaining walls, cribs, breakwaters, bridge abutments, etc., the element of color seldom enters. In the case of retaining walls and sidewalks, which are partially ornamental in nature, color should receive appropriate consideration.

II. INHERENT QUALITIES OF STONE

The capacity which a stone has to withstand the forces tending to destroy it, is known as durability, and depends upon the

mineralogical composition, and the texture or state of aggregation of the mineral constituents. A consideration of the mineralogical composition implies reference to the characteristics of the different kinds of minerals and their relative abundance. By texture is meant the size, shape, manner of contact, and arrangement of the mineral particles. The strength, hardness, elasticity, structures, the effect of alternating heat and cold, and the effect of acids, depend upon both the mineralogical composition and the texture. The specific gravity as ordinarily computed depends upon the mineralogical composition alone; the porosity on the texture; and the weight per cubic foot on the specific gravity, and porosity.[1]

Mineralogical composition.—The most common minerals that enter into the composition of building stones are quartz, feldspar, mica, calcite, dolomite, kaolin, pyroxene, amphibole, and serpentine. These minerals have a respective hardness of 7, 6, 2–3, 3, 3.5–4, 1, 5–6, 5–6, 3–4. With the exception of quartz they all have one or more well-developed cleavages.

Quartz is perhaps the commonest of these minerals. It is the hardest, but probably neither the strongest nor most elastic.[2] Under ordinary conditions of temperature and pressure it is little, if at all, acted upon by the common acids. These conditions, combined with the fact that it possesses no ready cleavage, makes it one of the most durable and stable rock-forming minerals.

Feldspar is also a very common mineral, especially in the igneous rocks. It is softer than quartz, but probably stronger and more elastic. It cleaves readily in two directions. Under ordinary conditions of temperature and pressure it is little acted upon by the common acids. In the quarry, decomposition of

[1] It has been customary to consider the minerals of igneous rocks as primary, and secondary, while the secondary mineral matter in sedimentary rocks is known as cement. In this paper minerals are considered without reference to their origin, and therefore the terms secondary, primary, and cement, have been purposely omitted.

[2] Thus far I have been unable to obtain the crushing strength or coefficient of elasticity of the common minerals. I expect that these constants have been determined although my attempts to obtain them have been unsuccessful.

feldspar takes place very slowly, but owing to the fact that it often occurs in granite and other rock of great age, it is frequently in an advanced stage of alteration. The alteration products of feldspar are objectionable only in so far as they yield more readily to disintegration.

Mica is also a very common mineral, occurring most abundantly in the metamorphic rocks. The ready cleavage by which the mineral splits into thin plates, provides an easy passage for water, by which disintegration proceeds more rapidly than in the associated minerals. Mica is undesirable in proportion to the size of the individuals. If present in small isolated flakes, as it ordinarily occurs in sandstone, it is scarcely less durable than quartz and feldspar, but if the individuals are large or the flakes clustered together, disintegration will proceed more rapidly. Decomposition through chemical agencies goes on very slowly.

Calcite is almost as common as quartz, although far less permanent at the surface of the earth. It possesses three prominent cleavage directions, on account of which it disintegrates quite readily. The hardness, and probably the strength and elasticity, are all less than in quartz. It is quite easily soluble in carbonated waters and is readily acted upon by cold, dilute hydrochloric acid.

Dolomite differs from calcite mainly in its somewhat greater hardness, and the greater difficulty with which it dissolves in cold dilute hydrochloric acid. Its cleavage, hardness, strength, and elasticity are such that it disintegrates almost as readily as calcite, although it is taken into solution somewhat more slowly.

Kaolin is an important constituent of slate, being however, mainly of secondary origin. It is one of the softer minerals, has a perfect cleavage, and readily disintegrates. It is not acted upon chemically except under the most favorable conditions.

Pyroxene is one of the less important building-stone minerals. It cleaves perfectly in two directions, and breaks down slowly through mechanical abrasion. It gradually decomposes in the quarry when in the presence of water.

Amphibole has about the same strength and capacity to withstand abrasion and chemical influences as pyroxene.

Serpentine occurs in certain green colored rocks, such as verde antique, and is usually an alteration product of olivine.

Among the accessory mineral substances in building stones may be mentioned *pyrite*, *marcasite*, *hematite*, *magnetite*, *graphite*, *and bitumen*. Pyrite and marcasite in which the iron occurs partly in the ferrous state decompose quite readily in the presence of moisture, forming ferrous sulphate, which is brought to the surface by capillarity and deposited as iron oxide. Through the decomposition of pyrite, occurring in limestone or dolomite, magnesium and calcium sulphates are formed, which are taken into solution and redeposited at the surface as a white efflorescence.

Hematite and magnetite frequently impart a red, brown, yellow, or black color to the stone, but are not considered harmful.

Carbonaceous matter occurs in the form of graphite, and bituminous matter in the form of petroleum. The gray and black shades of limestone and marble are often due to the abundance of graphite. Petroleum occurs mainly in limestone, and is objectionable on account of the discoloration which is apt to result from the adherence of dust.

The occurrence of gaseous inclusions in the minerals, especially in quartz, is said to be a cause for the shattering of a rock when subjected to high temperatures. To what extent these inclusions influence the results of high temperatures on rock is unknown. The probability is that any temperature which would make these gases active agents of destruction would destroy the rock through unequal expansion of the mineral particles.

The hardness, strength, elasticity, and resistance of the stone to chemical action and alternating temperatures is influenced by the relative abundance of the mineral particles. If the percentage of quartz is large, the hardness is proportionately great—provided the size, shape, arrangement, etc., are constant. The strength and elasticity also increase as the minerals in which these properties are best developed are increased. However, it must be understood that a mineral which is high in the scale

of hardness may have a comparatively low crushing strength and elasticity. Any increase in the percentage of this material will increase the hardness of the rock at the expense of strength and elasticity. Of course, the elasticity, hardness, and strength are not controlled by the one factor of abundance. A rock may consist entirely of the strongest minerals, and yet the size, manner of contact, and arrangement may be such that it will be one of the weakest.

TEXTURE OR STATE OF AGGREGATION

As outlined above the texture of a rock has reference to the size, shape, manner of contact, and arrangement of the mineral particles. The size of the particles affect the weathering of a stone by increasing the differential disintegration. When the mineral particles are large they disintegrate and weather out most easily, often leaving small depressions, on account of which the surface has a pitted appearance. The larger mineral particles have more pronounced cleavage cracks which increase the rate of weathering. Chemical agents have a better chance to operate and the stone is weakened throughout. Rocks which are composed of small mineral particles may have correspondingly small pore spaces, although the size of the pores is largely controlled by the shape and manner of contact of the grains.

The shape and manner of contact of the grains influence the strength and durability of the stone, as much perhaps as any of its other qualities. If the grains are close fitting the adhesion will be increased and the pore space decreased. When the grains are irregular in outline they usually interlock after the manner of dovetail work, which adds to the strength and lessens the pore space.

Upon the arrangement of the grains depends the laminated schistose, or cleavage structure in rocks. If the mica or other minerals are arranged with their longest axes in a common direction and concentrated along certain planes the rock will possess a capacity to part most readily in that direction and along those planes. The perfection of development of the parting capacity will be influenced also by the size of the grains.

The size, shape, manner of contact, and arrangement of the grains control the size of the pores and the percentage of pore space.[1] The porosity of a rock is an important factor, influencing the danger from alternate freezing and thawing of included water.

The pores, or spaces between the grains, which are connected in such a manner as to allow water to flow from one part to another have been divided for convenience into three classes.

The first class consists of small interspaces that exist between the grains of a rock, known as pore spaces; the second class consists of those openings which form along bedding, jointing, and fissile planes, known as sheet openings; the third class are those openings caused by the removal of several or many of the individual grains, commonly known as cavities, caves, or caverns. All of these openings frequently occur in the same rock.

Pores are ordinarily conceived of as being connected so as to form irregular-shaped tubes. Naturally they differ very greatly in size, depending upon the fineness and shape of the original particles composing the rock and the extent to which the interstices have been filled with secondary mineral matter. In the same rock all the pores are never of the same size, although they may have a general correspondence in size. The pores spaces are classified according to size into capillary and subcapillary. The capillary pores are the larger and the water which they hold is known as the water of saturation. Openings included in this class are over .00002 centimeter in diameter[2] If a rock containing capillary pores is allowed to drain off naturally, a portion of the water will escape, but another portion will

[1] It has been pointed out in another place that pore space in sedimentary rocks depends largely upon the size and shape of the grains and the amount of cement. In general this is true, but the cement itself becomes an individual grain, when once deposited in the interspace of a rock, and the shape and size of the cement grains should be considered. All particles of which a rock is composed should receive consideration as constituent grains of the rock.

[2] Metamorphism of Rocks and Rock Flowage, C. R. Van Hise, Bulletin of the Geological Society of America, Vol. IX, p. 272.

remain which is known as the water of imbibition. The subcapillary pores are conceived to be of such a size, smaller than .00002 centimeter in diameter, as to contain only the water of imbibition.[1]

As in the case of pores, Professor Van Hise has classified sheet openings which occur along bedding, jointing, or other fissile planes, as capillary and subcapillary, including in the latter all such as are less than .00001 centimeter in thickness.[2]

The third class of openings consisting of cavities, caves, and caverns are a result of the removal of one or more of the grains of which a rock may have been originally composed. They occur most commonly in limestone or dolomite, although present in other less readily soluble rocks.

III. EXTERNAL CAUSES OF DECAY

In the selection of a stone for any purpose a consideration of the climatic conditions under which it is to be placed, is of very great importance. A uniform climate in which the temperature is always above the freezing point is most favorable to long life. A dry climate is conducive to stability, while a moist or humid atmosphere promotes decay. A stone which will withstand the vicissitudes of a moist, temperate climate, where there are long seasons of alternate freezing and thawing, short hot summers, and cold winters, must be of the most enduring kind. The well preserved condition of the monuments of Rome and other cities of the Mediterranean basin, after centuries of exposure, is not due so much to the inherent qualities of the stone, as to the warm, dry atmosphere. The obelisk of Luxor stood for centuries in Egypt without being perceptibly affected by the climate, but after only forty years of exposure in Paris it is now filled with small cracks, and blanched.[3] The same is true of the obelisk in Central Park, New York, from which many pounds of small fragments have fallen.[4]

[1] *Ibid.* [2] *Ibid.*

[3] A. A. JULIEN: Tenth Census, Vol. V, p. 370.

[4] J. C. SMOCK: Bulletin N. Y. Museum, Vol. II, No. 10, p. 385.

The external forces of destruction may be conveniently considered in two classes: (1) those that produce changes through mechanical disintegration and (2) those that produce changes through chemical decomposition. In the case of disintegration the adhesion between the particles or the cohesion of the particles themselves is overcome, and the rock ultimately crumbles into sand or powder. In the case of chemical changes the identity of the mineral particles themselves is destroyed, by the minerals being broken up into other compounds.

The following is a general classification of the agents of mechanical disintegration and chemical decomposition:

I. AGENTS OF MECHANICAL DISINTEGRATION

A. TEMPERATURE CHANGES.
   1. *Unequal expansion and contraction of the rock and its mineral constituents.*
   2. *Expansion occasioned by the alternate freezing and thawing of the interstitial water.*

B. MECHANICAL ABRASION.
   1. *Water.*
   2. *Wind.*
   3. *Feet.*

C. GROWING ORGANISMS.

D. CARELESS METHODS OF WORKING AND HANDLING STONE.

II. AGENTS OF CHEMICAL DECOMPOSITION.

A. WATER-SOLVENT ACTION.

B. CARBON DIOXIDE.

C. SULPHUROUS ACIDS.

D. ORGANIC ACIDS.

Temperature changes.—Injuries to a stone through changes in temperature are occasioned in two ways: (1) By the unequal expansion and contraction of the rock and its mineral constituents, and (2) through expansion due to the alternate freezing and thawing of the interstitial water.

Unequal expansion and contraction of the rock.—The heat conductivity of stone is very low. A stone a few inches in thickness may be heated on one side to a temperature sufficiently high that it will not bear handling, while on the other side the stone may be comparatively cold. The actual expansion of different kinds of stone has been experimentally determined by W. H. Bartlett,[1] in which he obtained the following results:

Granite, .000004825 inch per foot for each degree F.
Marble, .000005668 inch per foot for each degree F.
Sandstone, .000009532 inch per foot for each degree F.

The diurnal changes in temperature in this latitude are often as much as 50° F., while the annual variation in temperature exceeds 150° F. A difference of 150° F. would make a difference of one inch in a sheet of granite 100 feet in diameter.

Each mineral of which a stone is composed has a different rate of expansion. Whenever a stone is heated each particle presses against its neighbors with almost irresistible force. When cooling begins, contraction sets in which initiates stresses pulling the individuals apart. The inequalities in the rate of expansion of the different mineral particles initiate stresses in rocks having a heterogeneous composition, which tend to separate the individual minerals from their neighbors. The result of these alternating temperatures is to weaken the rock and produce small cracks into which water may percolate or roots descend.

Besides the unequal expansion and contraction of the mineral particles, there is an unequal expansion and contraction between the different laminae or hypothetical layers of the rock which are near enough to the surface to be affected by the atmospheric temperatures. The layer at the surface suffers the greatest change in temperature, and is therefore most affected. Each succeding layer is less affected until a point is reached where there is little or no change in the temperature the year around. Owing to the rapid diurnal changes in temperature in some regions forces are constantly at work tending to separate the superficial stratum from those immediately below.

[1] American Journal of Science, Vol. XXII, 1832, p. 136.

The igneous rocks on account of their heterogeneous mineralogical composition, interlocking character of the mineral individuals, and difference in size, are more liable to injury from the diurnal changes of temperature than are the unaltered sedimentaries.

Investigation shows that, in arid regions, very great work is accomplished simply through expansion and contraction due to diurnal temperature changes. Merrill, in his "Rock Weathering," cites an instance in Montana where he found "along the slopes and valley bottoms numerous fresh, concave, and convex chips of andesitic rock, which were so abundant and widespread as to be accounted for only by the diurnal temperature variations. During the day the rocks became so highly heated as to become uncomfortable to the touch, while at night the temperature fell nearly to the freezing point."[1] Livingstone reports the temperature of rock surfaces in Africa to rise as high as 137° F. in the day, and cool off so rapidly by night as to split off rocks weighing as much as 200 pounds. The expansive force of heat is well shown in many of the limestone quarries in Wisconsin, where beds from five to six inches in thickness are for the first time exposed to the heat of a summer's sun. These thin beds become heated throughout their entire thickness and arch up on the floor of the quarry, generally breaking and completely destroying the stone.

Many buildings show the effect of weathering on the side exposed to the direct rays of the sun, while the sheltered side remains uninjured. The only rational explanation for this is found in the diurnal temperature changes. Ordinarily the movements due to temperature changes are necessarily small, but after centuries of time they must invariably result in the weakening and final disintegration of the stone.

Expansion occasioned by the alternate freezing and thawing of the included water.—The effects of diurnal temperature changes as described above, are small when compared with the action of continued freezing and thawing on a rock saturated with water.

[1] George P. Merrill: Rocks, Rock Weathering, and Soils, p. 181.

The expansive force of freezing water is graphically described by Geikie "as being equal to the weight of a column of ice a mile high, or little less than 150 tons to the square foot." One centimeter of water at 0° C. occupies 1.0908^{cm} in the form of ice at 0° C. It is this expansion of about one tenth that does the damage when confined water solidifies.

Water finds its way into the rocks through openings or hollow spaces which are everywhere present. Where the pores are large the stone contains water of saturation which is given off with comparative readiness, but the nearer the pores or sheet cavities approach those of subcapillary size, the greater is the tenacity with which the water is retained. One can readily understand how the particles composing a rock may be so closely fitted together, that the pores will be mainly of subcapillary size. Such a rock will contain only the water of imbibition which will be given off very slowly, on account of which the attendant dangers from freezing will be increasingly great. In general it may be said that the danger from freezing will be increasingly great as the pores approach in size those of subcapillary dimensions.

Two rocks, one of which has very minute interstices and the other of which has large pores may have a capacity to absorb equal amounts of water. The former, however, will be in much greater danger from alternate freezing and thawing. Of two equally saturated rocks, one with 10 per cent. and the other with 3 per cent. of pore space, in which the pores are of equal size, the more porous one will be in greater danger of freezing. The percentage of the pore space that is filled with water will also condition the results of freezing. If two thirds of a rock is saturated greater injury will result from its freezing than if only one third were saturated. If none of the pores are more than nine tenths filled with water, the effect of freezing will be nothing, because the increased bulk of the frozen water will no more than fill the spaces between the grains.

The amount of water contained in the pores at a given time depends, of course, upon the amount of water initially absorbed,

the time that has elapsed since absorption, the condition of the atmosphere, the size of the pores, and the position of the stone. It is only in exceptional cases that the stone in the wall of a building is saturated. However, if the pores are of greater than subcapillary size the water of saturation will, as a rule, be quickly removed, except in the lower courses below the water line.

It would, therefore, appear that the most important factor in estimating the danger from freezing and thawing, is the size of the pore spaces, which controls the rate at which the interstitial water is given up. The second factor of importance is the amount of water contained in each of the pores at the time of freezing. The third and last in importance is the total amount of pore space.

T. S. Hunt, in "Chemical and Geological Essays," says: "Other things being equal, it may properly be said that the value of a stone for building purposes is inversely as its porosity or absorbing power." This statement has been quoted by various authorities, one of whom says: "Other things being equal, the more porous the stone the greater the danger from frost." The mistake has often been made of estimating the danger from freezing by the capacity which a stone has to absorb water. Likewise the capacities which two stones have to withstand weathering are constantly being compared from the standpoint of the ratios of absorption. Such estimates and comparisons are very misleading, for one should not only know the capacity which a stone has to absorb water, but he should, above all, know and consider the relative size of the pores.

The injurious effects of the freezing of the "quarry water," as the interstitial water is called by quarrymen, has long since been known to contractors, who generally refuse to accept stone, especially sandstone, which has been exposed to the action of freezing before being seasoned. Where it is possible, quarrymen sometimes flood their quarry during the winter months, in order to protect the stone immediately at the surface.

The openings formed along bedding, jointing and other fissile planes, permit a freer circulation of water than the pores in the

rock. After an abundant fall of rain or when the snow melts in the spring, the cracks, crevices and pores in the rocks cannot carry away the water nearly as rapidly as it collects in these passages at or near the surface. If the temperature at such a time is fluctuating between freezing and thawing, the water will be alternating in a liquid and solid state. As the water congeals again and again the walls are pressed farther and farther apart. The ice acts as a wedge which automatically adjusts itself to the size of the crack, until the opening is sufficiently wide and deep to allow the free passage of the water. Not only are the cracks and crevices very much enlarged and extended through the stresses exerted by the solidification of the water but the stone is in itself materially weakened.

The danger from the freezing of water collected along parting planes must not be confused with the danger attendant upon the freezing of water which fills the pores of the rock. The compact, thoroughly homogenous rocks, without bedding or other parting planes, whether sedimentary or igneous, are in less danger from alternate freezing and thawing than those in which these structures occur.

Alternate freezing and thawing of the included water has been one of the most potent causes for the decay of building stone, more especially that stone which is bedded or otherwise laminated. The most disastrous results occasionally occur from using stone which has not been properly seasoned, and in cases where the stone has been laid on edge instead of on the bed. In the first case the stone is materially weakened throughout by freezing, while in the latter exfoliation or scaling is liable to ensue. The most trying place in a building, in which to place a stone, is at the "water line," where saturation is most common and the greatest alternations of freezing and thawing occur. The conditions are more severe in the case of bridge abutments and retaining walls than elsewhere. In bridge abutments the courses of stone at the level of the water are often badly shelled and broken, while the stone above and below is scarcely injured. It is not uncommon to observe all the courses of a retaining wall

in a dilapidated condition after it has been built a comparatively few years. When the snow melts in the spring the water sinks into the ground and issues through every crack and crevice in the wall. As it collects along these fissile planes it freezes and wedges apart the laminæ of the rocks.

Because the sedimentary rocks more frequently have parting planes than the igneous, they are as a class more apt to suffer from alternate freezing and thawing. On the other hand the sedimentary rocks are sometimes as free from parting planes as the igneous, and are accordingly in as little, or even less, danger from freezing.

The openings known as caves, caverns, and cavities need not occupy our serious attention. Cavities occasionally occur in both sedimentary and igneous rocks used as building stone, but mainly in the former. They do not increase the danger from freezing, owing to the fact that they are seldom filled with water when near the surface. They weaken the rock slightly and often occasion a roughness of the face when they occur at the surface. The cavities are often partly filled with impurities, such as pyrite, which may injure the rock, through the readiness with which they decompose.

From the foregoing we may conclude that an ordinarily well cemented sandstone, which is free from parting planes or stratification, and in which the pores are of greater than subcapillary size, is best suited to withstand alternate freezing and thawing when placed in the wall of a building; assuming that the original strength of the stone is sufficient for the position which it occupies in the wall.

Mechanical abrasion.—One of the most important agents of disintegration in nature is mechanical abrasion, but the rôle which it plays in the destruction of artificial structures is not nearly as important as that of certain other agents.

Mechanical abrasion is accomplished mainly by wind, running water, and shuffling feet working in conjunction with the other agents of disintegration. The beating of the rain against the stone wall may overcome the adhesion between the rock

particles, separate them from one another, and carry them away. These particles may, in turn, as they are carried down the side of the building, wear off other particles, and so on until the bottom is reached. The effects of drifting sand, that are such conspicuous features of the arid regions, are very slight in the temperate zone in which we live. Drifting sand contributes an almost insignificant part to the whole process of disintegration. J. C. Smock, in his report on the building stone of New York, mentions the fact that the ground glass character of many of the window panes in some of the older houses of Nantucket are due to driven sand. The windward sides of many of the monuments in the older eastern cemeteries have lost their polish, while in some cases even the lettering has been destroyed by this same agent. The monuments in the cemeteries of Wisconsin which are located in sandy regions are beginning to show the effects of wind-blown sand. The polish is dulled and the lettering is becoming indistinct.

Besides being subject to the action of wind-blown sand and rain, stone is often used in places where it is abraded by thousands of feet passing over its surface. There is a great difference in the capacity which different stones possess to withstand abrasion. Sidewalks, pavements, and steps may be seen in every city which are more or less worn by constant shuffling of feet over their surfaces.

Growing organisms.— It is a very common occurrence to find lichens and algæ covering the surface of a rock in a quarry. Trees may also be observed sending their roots deep into the crevices and cracks of the rock, and by their growth and expansion huge blocks are often broken from the parent mass. In some of the very soft rocks the writer has observed the finer rootlets ramifying through the body of the rock itself, destroying the adhesion which bound the particles together. Decaying plants are also known to give off organic acids which aid in the decomposition of the rock. Fungi and algæ often attach themselves to the stone, frequently almost entirely covering the exposed surface. The most common form of plant growth

occurring thus is the lichen, which often covers the surface of the rock after the manner of a mat, thereby exerting a protective as well as a destructive influence. The covering which they form serves as a protection against the atmosphere, while the acids incident upon their decay and the mechanical effects of their rootlets penetrating between the grains are a slow cause of disintegration. Algæ are also common, and often occur on the damp parts of a wall, causing discoloration through their own decay and the lodgment of fine dust particles. The effect of allowing creeping vines, such as ivy, to cover the walls of buildings is picturesque, but the practice is certainly injurious to the life of the stone.

Careless methods of working and handling.—The natural forces of destruction have been greatly accelerated, either through the ignorance of quarrymen and their total disregard for proper time and methods of quarrying, or through the carelessness of workmen in cutting, carving, and laying the stone used in building construction. There are probably thousands of buildings, constructed out of stones, the lives of which have been shortened at least one half by improper methods of quarrying and handling.

Quarrymen have been found moving stone with heavy charges of powder, or even dynamite, expecting to obtain dimension stone for building purposes. The heavy charges of powder not only destroy a large amount of stone, but they also shatter the cement and produce incipient joints in the blocks which may accidentally remain in dimensions sufficiently large for building purposes. The destruction of the cement and the production of incipient joints not only weaken the rock, but also facilitate the entrance of water, with the attendant dangers from freezing, with which we are already familiar. This method of quarrying not only materially lessens the value of the salable stone, but hundreds of tons of otherwise marketable stone is absolutely destroyed. The use of heavy hammers and sledges in splitting the stone, by striking continuously along one line, shortens the life of the stone in the same manner as heavy blasting.

Much care should be exercised in quarrying stone in order to prevent these unnecessary injuries. So far as practicable, quarrymen should take advantage of the natural joints. Whenever blasting becomes necessary, the Knox system of small charges, properly distributed, is reported to be the least injurious of any method yet employed. The channeling machine, however, is the best method of reducing the stone to dimensions that can be easily handled. Especially in working sandstone and limestone this machine can be employed to advantage.

The time of cutting and dressing stone may also influence in a small way its life It is generally known that during the process of seasoning the water which comes from within the rock evaporates and deposits mineral matter which forms a crust on the surface of the stone. This crust may be formed entirely by the evaporation of the original interstitial water, or it may be added to by water which has been soaked into the stone at a later period and been subsequently brought to the surface.[1] That water, which has been called the water of imbibition, probably carries a much larger percentage of mineral matter in solution than the water of saturation. The water of imbibition is the last of the quarry water to leave the stone, and therefore the crust is not likely to be well formed until the rock has been thoroughly seasoned. If the stone is to be seasoned before being placed in the wall, it is advantageous to have it first cut, dressed, and carved. Not only is it advantageous to observe this rule from the standpoint of future durability, but also from the fact that the stone often works much more readily when first quarried than it does after it has been seasoned. After a crust has once formed it should not be broken, because the softer rock underneath, when exposed at the surface, will disintegrate much more rapidly. For these reasons most stone should be worked and finished, ready for laying in the wall, before it has been thoroughly seasoned.

[1] The addition through saturation and evaporation after the quarry water has been driven off is probably an almost unappreciable amount, depending upon the amount of mineral matter originally in the water.

The manner of dressing a stone also influences in a small way the length of its life. A stone which has polished surfaces sheds water much more quickly and is disintegrated much more slowly than one with rough surfaces. The stone with rough surfaces has many crannies and crevices, in which the water collects and is finally absorbed. Sandstone which has been hammer-dressed is liable at first to disintegrate faster than that which has been sawed, due to a weakening of the cement by the impact of the hammer. In general, it may be said that polished and sawn surfaces shed water most readily, while those that are rock-faced or hammer-dressed, on account of their rough exterior, absorb a considerably larger percentage of the water which falls on their surfaces.

Before a stone is used in the construction of a building it is safer to have at least the water of saturation driven off. As a rule quarrymen are acquainted with the effects of frost upon stone in which the water of saturation still remains, and observe the necessary precautions. There are quarrymen, however, interested solely in the disposition of their stock, who impose upon the ignorance of the public by selling stone which has not been seasoned. Stone should be seasoned not only to escape the danger from freezing, but also to insure safety in handling and laying.

The exfoliation of sandstone in the large eastern cities has been mainly attributed to the fact that much of the stone has been laid on edge instead of on the bed. Laying stone on edge has been practiced at all times, owing to the greater readiness with which stratified or schistose rocks can be dressed along the bed. The greatest tendency to lay stone on edge is encountered in veneer work, but is occasionally met with in heavy masonry.

If the parting planes, which ordinarily furnish the easiest paths for percolating waters, are normal or inclined to the surface of the earth, they will admit the passage of water much more readily than if they are parallel. Thus if a block of stone is placed on edge in a wall, there will be greater danger from the

freezing of the included water than if it were laid on the bed. In case the stone is laid on edge, the pressure required to split off lamina will ordinarily be much less than if the stone is laid on the bed. In the first case the force occasioned by the freezing of the water which collects between the layers is augmented by the superincumbent pressure of the wall. If the stone is laid on the bed, the water is less apt to penetrate along the parting planes, and even though it should circulate with equal freedom in this position, the superincumbent pressure of the wall would tend to force the expansion in directions parallel to the bedding.

Furthermore, when stone is laid on edge the difference in texture of the various laminae are much more strikingly emphasized than where the stone is laid on the bed. When laid on edge the different blocks, as a whole, will exhibit different rates of wear, instead of the minor inequalities ordinarily shown by the different laminae when the block is laid on the bed.

In important structures one ought to avoid laying any stone on edge which shows stratification or schistosity for the reason that in this position it is inherently weaker and permits a more ready absorption of water, with the attendant dangers from alternate freezing and thawing.

AGENTS OF CHEMICAL DECOMPOSITION

In artificial stone constructions the decomposition of the mineral constituents of a rock proceeds much more slowly than disintegration. The forces which are at work breaking down the chemical compounds have a much greater task to perform than those which have simply to overcome adhesion and cohesion.

Water.—The active agent producing chemical changes in the rock is water. Water generally contains in solution, besides mineral salts, one or more acids, either sulphuric, sulphurous, carbonic, or organic. Thus the water is often a very dilute acid solution. As it percolates through the rocks it dissolves small quantities of mineral matter in one place and deposits it in another. Through these agents the minerals composing the rocks of both the igneous and sedimentary series are decomposed, and transfers of large quantities of mineral substances take place.

In the case of building stone the chemical decomposition of the minerals is so exceedingly slow that it seldom affects the strength or life of the stone after it has been placed in a building. Only in the case of limestone, dolomite, or marble, or where iron sulphide or iron carbonate occur in other rocks, is any material deterioration noticeable.

Sulphurous acids.—In the case of decomposition of iron sulphide, in the presence of moisture, the formation of iron oxide is the most conspicuous, although not the only result. The decomposition of the sulphide produces sulphurous and sulphuric acids which, in the case of dolomite, act upon the magnesium carbonate, producing magnesium sulphate, which is often brought to the surface and deposited as an efflorescence or incrustation.

The sulphurous and sulphuric acid gases are mainly present in the atmosphere of large cities where there is a large consumption of bituminous coal. The action of these acids is largely increased if the atmosphere contains a considerable amount of moisture. In London, where fogs predominate and the consumption of soft coal is very large, there seems to be little question but that the effect of these gases is worthy of careful consideration. But in the United States, with the exception of a few of the larger cities, the influence of these agents is comparatively small and needs but a passing mention.

Carbon dioxide.—Wherever water heavily charged with carbonic acid gas is passed through calciferous rocks, more or less of the calcium carbonate is dissolved, lessening the adhesion between the different particles and weakening the rock. In nature the results of this process are very great, but the carbon dioxide has scarcely any appreciable affect on the durability of stone in the walls of a building.

Organic acids.—The influence of organic acids resulting from decaying organisms on the life and strength of a rock, especially in the walls of buildings, is so slight as to barely warrant mention.

E. R. BUCKLEY.

EDITORIAL

THE meeting of the Committee on Rock Nomenclature, appointed by the International Geological Congress, which was held in Paris last October, failed to elicit concerted action on the part of petrographers. Only two reports were received from committees representing different countries. They were from Russia and France, and will be transmitted to the Congress. The small attendance at the meeting, the wide divergence of views indicated by members expressing themselves by letter, and the desire of independence manifested by all, make it impossible for the committee as a whole to transmit a report to the congress. Each petrographer is expected to present his views in his own way at the coming meeting in Paris.

Apparently there has been no progress toward harmony of nomenclature or of rock classification. There is still a wide divergence of ideas concerning rocks themselves and the methods of dealing with them. While this is to be regretted, it is not to be wondered at, considering the abstract petrological, as well as the anthropic, elements involved in the problem. However, there are indications of advancement along more or less converging lines that will eventually unite. In the meantime every petrographer is a law unto himself, as is evident from articles recently published in this JOURNAL and elsewhere.

PROFESSOR HOBBS, in his discussion of this subject in this volume of the JOURNAL, has laid special emphasis on the value of diagrams in conveying ideas of relative quantities of chemical constituents of rocks, availing himself of Brögger's modification of Michel-Lévy's diagrams. The importance of such devices for expressing relative quantities and for permitting ready comparison of many variable factors in an intricate problem cannot

be overestimated. They not only fix in an easily comprehended form facts already vaguely apprehended, but often suggest relationships not previously suspected. With all machines the product turned out depends on the material operated on. And while the machine itself may be perfect, the product may be open to criticism.

The diagrams in question tend to give more definite impressions of the relative quantities of the chemical elements in rocks than are obtained from the usual statements of analyses. But, if instead of actual rock compositions there is substituted an average of various rocks, it is clear that there is danger of placing too much value on the apparently definite expression conveyed by the composite diagram. Everything depends upon what rocks have been grouped together. Defects in grouping vitiate the diagram. For this reason it is desirable to distinguish between the use of graphical methods of presenting an assemblage of diverse quantities, which is highly commendable, and the practice of averaging diverse quantities, which is open to serious criticism.

J. P. I.

Reviews.

Om klimatets ändringar i geologisk och historisk tid samt deras orsaker. [On Changes of Climate in Geologic and Historic Time and their Causes.] By Nils Ekholm, *Ymer*, Årg. 1899, H. 4, pp. 353–403. Published by Svenska Sällskapet för anthropologi och geografi, Stockholm.

The first section of the paper discusses, in a general way, the causes of telluric temperature changes. The author states at the outset that the temperature of the earth depends upon the ratio of the amounts of insolation and radiation. He thinks that the solar radiation has very likely not been subject to any considerable changes during the time the earth has been an abode of life. But the transparency of the atmosphere to different kinds of heat rays, and hence also to radiation, has, no doubt, varied greatly and caused the great changes in climate known to geology. Only in the second place would he put the eccentricity of the earth's orbit and the inclination of its axis as a cause of climatic changes. He does not think that the eccentricity of the earth's orbit has caused any climatic variations which have left traces known to geologists. But the variations in the inclination of the earth's axis have caused changes of considerable magnitude in the polar regions, and in the adjacent zone, at least as far down as the latitude of 55° in the northern hemisphere.

The old notion that the internal heat of the earth has appreciably affected climatic conditions in geological time must be set aside. The earth was, no doubt, at one time in the same condition in which we now find the planet Jupiter. There was a dense atmosphere filled with steam. After the temperature of this atmosphere of the cooling globe sank below the boiling point of water its vapor rapidly (in a few hundred years) condensed to a boiling sea. While the convection of this sea was in effective action, the temperature of the sea bottom, the upper crust of the earth, was rapidly lowered, which caused the outer crust to crack open as it contracted relatively more rapidly than the interior. This process went on until the radiation of the crust outward

(which grew less and less) equaled the conduction from below. Then there was a resting time. The cracking ceased. Later the conduction of heat from the interior to the crust was smaller in amount than the radiation from the surface. As a result lateral pressure was developed and caused the rise of the land above the sea here and there in folds.

The paper then proceeds to offer proof that the conduction from the heated interior is vanishingly small at present compared with insolation, hence it can cause no appreciable rise in temperature now.

There follow some paragraphs on geological time and the probable age of life on the earth. The author quotes some computations "made by T. Mellard Reade and communicated by Chamberlin" relative to the age of the sea (JOURNAL OF GEOLOGY, Vol. VIII, p. 572). The computations referred to were made by Chamberlin, though this is not explicitly stated in the paper quoted. The estimates made by Nathorst, Phillips, and Geikie are given. The calculations of Lord Kelvin are also discussed. He is said to have made use of such assumptions that the results attained can hardly be regarded as anything more than a mathematical exercise without bearing on the physical problems involved. It is maintained that there are no physical data disproving the high estimates of geological time favored by geologists and biologists.

The headings of the third part of the paper may be rendered as follows: Insolation nearly constant during geological time; changes in the quantity of carbon dioxide in the atmosphere the principal cause of the great climatic changes; the cause of the change in the quantity of carbon dioxide in the atmosphere. The author refers to Lord Kelvin as having made calculations on radiation from the sun, and having reached the conclusion that the mean temperature of the sun has been constantly rising. The author has carried out further these computations in a paper just submitted to Kongliga Svenska Vetenskaps Akademien, entitled *Ueber den Energie-Vorrath, die Temperatur und Strahlung der Weltkörper*, and finds that the rise in the mean temperature of the earth has been compensated by the diminution in the surface of the sun and also by the decreasing efficiency of the convection currents from the interior to the exterior of the sun. Possibly the radiation was less than it is now at the time when the sun's radius was sixty times its present length.

Then follows an account of the researches of Arrhenius. From these some conclusions are drawn. It is estimated that a diminution

of the carbonic acid in the atmosphere to two thirds of its present amount would probably reduce the temperature of the polar regions by 5° C., and a tripling of the present amount would increase the temperature there by 18° to 20° C., the temperature of the Cretaceous period. A few paragraphs are devoted to discussing the amount of carbon dioxide, the cause of its fluctuations. Using a commercial simile, he remarks that the exchanges between the CO_2 consuming processes and the CO_2 yielding processes are carried on with a very small capital, and hence they are proportionately rapid, and as a result are subject to great and fortuitous changes. New carbonic acid is furnished by volcanic activities (Chamberlin, JOURNAL OF GEOLOGY, Vol. VI, p. 611), and by meteors bringing it into the upper atmosphere. Pursuing his commercial simile he remarks that the reserve fund is in the sea. Chamberlin is again quoted on the effect of lime-secreting organisms in the sea and as to the chemical condition of the carbonic acid in the sea.

Over the first ocean the atmosphere very likely became, as time went on, more and more impregnated with carbon dioxide. This is supposed to have taken place after the conduction of heat from the earth's interior had ceased to have climatological importance. This increase of carbon dioxide is believed to have resulted in the rise of temperature which affected the crust of the earth. The temperature of the early Cambrian age is hypothetically placed at 20° C., with a rise during the period of 10° higher temperature. It is estimated that this rise of temperature would cause folds four kilometers in height, if the expansion were concentrated so as to have caused rising in any single place. In a similar way mountains are held to have been formed in the Carboniferous age. By erosion large amounts of the carbonates were carried to the sea, favoring the life of carbonate-secreting animals. By the increase of land and of temperature the consumption of CO_2 was increased, resulting in the withdrawal of much of it. Thus the cold of the Permian age was brought on.

The progressive cooling of the surface temperature during the Permian age is also discussed. A change from 30° to 10° C. is assumed. This brought about a contraction of the outer shell relative to the inner kernel of the earth. The computed relative shrinking of the outer shell is 12.8 kilometers. This shrinkage brought on extensive cracking and volcanic activity, and thus led to an increased production of carbon dioxide. Thus warm climate again resulted, probably lasting

during the Cretaceous and into the Tertiary period. A subsequent period of folding and withdrawal of carbonic acid resulted in the great ice age. After several less well-known climatic changes—some geologists count as many as six different ice periods—the recent period finally arrived with its temperate climate, in which we still live.

To the fundamental causes here discussed as affecting the climatic changes of long duration, a secondary cause may be added, as pointed out by Chamberlin, namely, the continued erosion and denudation of the continents by precipitation. It is evident that this cause intensifies the climatic conditions between cold and warm periods. In a note (p. 375) the author leaves it to the future to decide whether the interglacial periods are due to changes in the atmosphere, or to changes in the inclination of the earth's axis.

Since the cooling of the polar regions of the earth have, on the whole, always been in advance of the cooling of the tropical and temperate zones, our greatest mountains lie in these latter zones. The polar caps have attained a greater solidity and resistance to pressure, and thus the folding has been mostly transferred to other regions.

The sea has served as a great moderator of the climatic changes of long period. *The cause of the latter must be sought in the alternate contraction and expansion of the earth's crust following changes in the mean temperature of the atmosphere.*

The fourth part of the paper has for its subject *the changes in the inclination of the earth's axis to the ecliptic and its influence on climate.* Here is first given a summary of the evidence of changes in the flora and fauna of northern Sweden, since the ice left the peninsula. Since the time of the "Oak zone," the average temperature has fallen 2° C., judging by the fossil distribution of Hazel. Possibly the winter temperature was but little different from the present. Accepting the archeologist's figures as to the time of the appearance of paleolithic man in Sweden, 7000 to 10,000 years back, the highest temperature of the climate of Sweden seems to have occurred at that time. The author then proceeds to show that the Quaternary changes of climate can be readily and fully accounted for by the "long-periodic" changes in the inclination of the earth's axis. He has tabulated Stockwell's calculations (p. 381). These show the inclination to have been small about 9000 years ago, and that it has been increasing since then. He presents a calculation of the length of the mid-summer day (the sun not setting) for Karesuando, the northernmost meteorological station

in Sweden, at the latest minimum and maximum of inclination, respectively 9100 and 28,300 years ago, thus:

28,300 years ago - -	38 days
9,100 years ago - - -	62 days
At present - - -	54 days

Then follow tables showing calculated temperatures (in terms of excess and deficiency compared with the present) for different latitudes during the months of the year at the last maximum (28,300 years ago) and the last minimum of inclination (9100 years ago) north of 80° N. latitude. There was, 28,300 years ago, a deficiency of 5° C. In Sweden the deficiency was from 3½° to 2° C. These figures are all for the summer months. The author is uncertain as to the winter temperatures. In Sweden these would perhaps depend on the gulf stream, as at the present; 9100 years ago the summer heat was 2° to 1.3° C. higher than now, while the winter temperature is uncertain. A time with hot summers occurred 48,000 years ago. Geologists know of no other period of greater heat than the present, except the one 9000 years ago, *since the end of the last glaciation.* The end of the ice age, hence, cannot have occurred earlier than 50,000 years ago. Possibly it is later, but the greater summer insolation 48,000 years ago may have helped in melting the ice.

The last section of the paper relates to *climatological changes in historic time, especially in northwest Europe.* The author discusses recorded observations on the forming and thawing of ice on various Scandinavian waters, ancient stock-raising in Greenland, grape culture, etc., and concludes that the winters have grown milder and the summers cooler during the last 300 years. Some conclusions are drawn from a study of weather records made by Tycho Brahe. A comparative table of snow precipitation for Brahe's time and the present is given as follows.

PER CENT. OF DAYS WITH SNOW OUT OF TOTAL DAYS OF PRECIPITATION.

Years	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1582–1597 (Time of Brahe) -	3	14	38	45	75	63	21
1881–1898 (Present) - -	2	16	37	48	53	46	19

By comparing this table with current temperature, he finds that it is likely that 300 years ago February was 1.4° C. colder than now, March 1° C. colder, and the other months differed either way by less than .2° C.

Finally the author discusses secular temperature changes as indicated by thermometric measurements made in the last 100 or 150 years, and concludes that at Haparanda, Stockholm, and Lund, in Sweden, the January temperature has risen during this time 1° C., while that of August has become somewhat cooler. At Lund, April, June, September, and October temperatures have remained unchanged.

The paper contains five figures. One of these shows the fossil and present distribution of Hazel in Sweden.

This article is particularly interesting to one who has previously read Chamberlin's papers on the same questions. There are several points of coincidence in the two. One of the authors is a meteorologist, the other a geologist, by profession. On the main cause of long-periodic changes of climate both agree. In accounting for minor details the geologist favors meteorologic causes, while the meteorologist seems inclined to accept, with a modification, a hypothesis which has been quite generally favored among geologists.

J. A. UDDEN.

Sveriges temperaturförhållanden jämförda med det öfriga Europas. [The Temperature Conditions of Sweden compared with those of the rest of Europe.] By NILS EKHOLM, *Ymer*, Årg. 1899, H. 3, pp. 221–242. Published by Svenska Sällskapet för antropologi och geografi, Stockholm.

The only portion of this paper that has obvious geological bearing is the statement that the temperature conditions of Sweden, especially the cold winters which sometimes occur, are to be explained rather by exceptional conditions favorable to radiation than by cold winds coming from Siberia. The author shows, among other things, that the recurrence of cold winters in Sweden exhibits a quite definite periodicity of five and two thirds years, or half the length of the sun-spot period.

J. A. UDDEN.

Physiography of the Chattanooga District in Tennessee, Georgia, and Alabama. By C. WILLARD HAYES. United States Geological Survey. Part VII, Annual Report, 1897–8.

In this report the author has done what Gilbert did in his "Geology of the Henry Mountains," namely, has made a study of a region

where the conditions are more or less simple, with a view of establishing principles which may be used in regions of greater complexity. The region concerned is situated in southeastern Tennessee, northeastern Alabama, and northwestern Georgia. It is bounded by the meridians of 84° 30′ and 86°, and by parallels of 34° and 36°, and comprises nearly 12,000 square miles.

The problems considered are as follows: (1) The forms assumed by maturely adjusted streams in a region where the strata are faulted and folded, and where metamorphism has so affected the rock that the original differences have been diminished, leaving a somewhat homogeneous series; (2) the forms assumed by streams when the strata are practically horizontal, and where the beds vary greatly in hardness; (3) the processes by which consequent drainage in a region of folded strata is transformed into subsequent drainage, with the development of anticlinal valleys and synclinal ridges; (4) the present altitude of former base-levels and the determination of the deformations which the region has suffered in recent geological time. These problems are considered under two main heads, namely, "Geomorphology" and "Geomorphogeny."

The Chattanooga district embraces a part of each of the five natural divisions into which the southern Appalachian province has been divided by Powell.[1] Within this region Hayes finds three types of topography: (1) The Western type, including the Cumberland plateau and the Highland Rim, a part of the interior low lands; (2) the Central type, and (3) the Eastern type.

(1) The first or Western type is separated from the other divisions by the Cumberland escarpment, which forms the eastern boundary of the Cumberland plateau. In the northeastern portion of this district streams have hardly begun to cut in the plateau, while to the south and west only remnants of the plateau remain, each remnant retaining the characteristics of the original highland. The plateau is about 1800 feet above sea level, the Highland Rim about 1000 feet, while the low lands, which stretch northwestward to the Ohio River, have an altitude of but 600 feet. Thus it is seen that the Highland Rim is a terrace between the Cumberland plateau and the lowland. (2) The Central type is that of the Great Valley, in which there are three levels or sets of levels. The valleys of the Tennessee and the Coosa rivers are from 600 to 700 feet above sea level. One series of valley ridges reaches

[1] Physiographic regions of the United States: Nat. Geog. Mag., Monograph No. 3.

altitudes of from 900 to 1100 feet, and another altitudes of from 1500 to 1700 feet. (3) The Eastern type comprises the Unaka Mountains and the western portion of the Piedmont Plain.

The formations of this region are divided into two groups: (1) The unaltered sedimentaries which are of varying degrees of hardness and solubility, and (2) the metamorphic and igneous rocks.

The twenty-three formations of the Paleozoic are divided into five subgroups: (1) The lowest six Cambrian formations consist of conglomerates, quartzite, and siliceous shales, and are nearly insoluble. These form the rocks of the Eastern division. (2) Ten Cambrian and Silurian formations, composed for the most part of limestone and shales, are relatively soluble. These occupy the greater part of the Valley or Central division, while a few beds of sandstone and the Knox dolomite give rise to the valley ridges. (3) The Upper formations of the Silurian and the formations of the Lower Carboniferous are the rocks which form the Highland Rim, and also some of the valley ridges. (4) On account of their solubility, the Lower Carboniferous series gives rise to the characteristic topographic forms in the Western division. (5) The durable Coal Measures conglomerates cap the Cumberland plateau and have occasioned the preservation of large areas of its surface.

The second group of rocks, that is, the igneous-metamorphic group, comprises, (1) the feldspathic (easily eroded) rocks which form the larger part of the Piedmont plateau, and (2) the non-feldspathic (resistant) rocks which have given rise to the irregular topography of the Unakas.

In this region Hayes makes out three peneplains or base levels, namely, the Cumberland base level, the Highland Rim base level, and the Coosa base level.

The altitude of the reconstructed Cumberland base level at its southern edge is about 1200 feet. From this altitude it increases to a height of 2000 feet in the central part, and decreases again to 1600 feet along its southern and eastern edges. This gives a gradient of ten feet per mile from the edges to the center, which is steeper than a base level grade should be, and, besides, no base level tract should have such a shape unless drainage radiated from its center, and this does not seem to have been the case. Hayes explains the present form by the hypothesis that in being elevated to its present position the base leveled region was warped into the form of a low dome. Upon

the peneplain are a few remnants above the general level. The Cumberland base-leveling epoch came to an end with the uprising at the end of the Cretaceous.

The Highland Rim is the peneplain next below the Cumberland. It retains a very uniform height, the difference between the northern and southern edges being but little more than existed during the period in which it was base leveled. Upon this plateau also there are monadnocks which represent areas of more resistant rocks.

The altitude of the lowest and youngest peneplain is 700 feet at the south and 800 feet at the northern edge. Here, as upon the other plateaus, there are considerable variations in altitude in different parts of the peneplain. These should not be taken as indicating distinct base levels, but simply the influence of local conditions.

Hayes considers two hypotheses in explanation of these peneplains, namely, subaërial denudation and marine denudation. He finds support for the former only.

The streams of this region belong to three distinct river systems, the Cumberland, the Tennessee, and the Coosa. They are the main agents which have shaped the present topography. There have been periods of stability and relative inactivity, alternating with great revolutions. It is hard to follow all these changes in detail, for the history of each change is in some measure obscured by that of the next. The first cycle of erosion resulted in the formation of the Cumberland peneplain. This cycle began when the land was raised at the end of the Carboniferous, and ended with the uplift closing the Cretaceous. This long period of erosion was not a single cycle, but was composed of a number of more or less distinct cycles, the evidence of which remains even to this day. Hayes has worked out the general courses of the Paleozoic streams in some detail, but no statement would be intelligible without the maps.

When the Cumberland peneplain was raised and warped, and the second cycle of erosion inaugurated, there were signs of activity all along the line. The sluggish streams began again to cut their beds and to fight for the mastery of favorable positions. The development of new streams at the expense of the old, changes in the direction of drainage, and final, almost perfect, adjustment of the streams in this cycle are carefully worked out by the author. This second cycle, while much shorter than the first, extends over a vast period of time. It ended, as did the Cumberland, by a rise of the land and a slight

warping of the surface. The streams again began to adjust themselves to their new conditions, a work in which they are still engaged.

Hayes has made out the following changes which the streams have gone through in reaching their present courses. First, they moved westward to the interior sea as antecedent streams during the first cycle. Then they were diverted southward to consequent courses, and at last flowed westward as subsequent streams.

The way in which peneplains are correlated forms an interesting section of the paper. The types of stream basins as found in the region are vividly described. The maps, of which there are five, repay careful study.

F. H. H. C.

Geology of Minnesota, Final Report, Vol. IV. By N. H. WINCHELL, U. S. GRANT, WARREN UPHAM, and H. V. WINCHELL. Quarto, pp. i–xx, 1–630, with 31 geological maps, 48 photographic plates, and 114 figures. St. Paul, 1899.

This volume, which completes the areal geology of the state, follows its predecessors in the geographic arrangement of the subject-matter. The area covered embraces the northern third of the state, and includes some thirty counties and districts. The bed rock of the region, with the exception of scattered patches of Cretaceous, is almost universally crystalline in character, and is referred to the Archean and Taconic. The thickness of the drift is very great throughout most of the region considered, several counties in the northwestern part of the state presenting no outcrops whatever of the bed rock.

The crystalline rocks in this largely new field have naturally received much attention, resulting in the accumulation of a considerable mass of new facts relating to the Archean and Taconic, especially the former. The interpretations based upon these facts differ considerably from the commonly accepted views as to the character and divisions of the ancient crystalline rocks, and especially as to the assumed representative of the original crust of the earth.

It is to be regretted that the first presentation of a new classification should be somewhat lacking in clearness, but nowhere in the volume is there a satisfactory statement of the divisions into which the various clastic and igneous rocks of the state have been separated, nor of the equivalents in the ordinary classifications. As nearly as

may be judged from the report, the classification of the pre-Silurian rocks adopted by the survey is as follows:

Cambrian (St. Croix, "Potsdam") (Upper Cambrian)		
Taconic (Lower Cambrian)	Keweenawan	Potsdam (clastic) and Manitou (igneous)
		. . . .
		Cabotian (igneous)
	Animikie	
	. . . .	
Archean	Upper Kewatin	
	. . . .	
	Lower Kewatin	

I. ARCHEAN

1. *Lower Kewatin.*—The rock of the Lower Kewatin is in general designated by the survey as greenstone, and is composed of two divisions: (1) A lower massive igneous greenstone, assumed to represent the original crust of the earth, and (2) an upper series, partly fragmental and partly chemical, including beds of basic tuff, of agglomerate, and of conglomerate, the jaspilytes and iron ores of the Vermillion range, and vast masses of quartz-porphyry. Both the jaspilytes and the porphyry are tentatively held to be the result of chemical precipitation in the Archean ocean, the apparent dikes of the porphyry in the Upper Kewatin being considered as infolded masses, or as intrusions brought about by plasticity due to the subsequent application of heat and pressure.

2. *Upper Kewatin.*—The Upper Kewatin consists of a basal (Ogishke) conglomerate, overlaid by a series of graywackes, argillytes, and a single jaspilyte. The fragmental members are characterized by the presence in greater or less amounts of greenish material supposed to have been largely derived from the waste of the lower Kewatin, and from the Archean volcanoes. The whole series is involved with the Lower Kewatin in vertical isoclinal folds.

All the members of the Kewatin, both Lower and Upper, have been locally strongly metamorphosed, giving rise to clastic gneisses, schists, etc., where the action was simply one of recrystallization, and

to granites, syenites, diabase, gabbro, etc., where complete hydrothermal fusion took place.

II. TACONIC

This is considered as the time equivalent of the Lower Cambrian, and is separated from the Upper Kewatin by a marked unconformity. It is separated into two divisions, the Animikie and the Keweenawan.

1. *Animikie.*—The Animikie consists of a series of graywackes, slates, and quartzites, and the Mesabi iron ore series. The beds vary in dip from nearly horizontal to 45°. There are no known contemporary lava flows, but the rocks are characterized by the presence of numerous sills and dikes of diabase intruded during the interval separating the Animikie from the overlying clastics (Potsdam).

2. *Keweenawan.*—The clastic part of the Keweenawan is considered as Potsdam and is separated from the Animikie by a distinct unconformity. It begins with a basal conglomerate, usually red in color and of varying coarseness, known as the Puckwunge conglomerate, and is followed by quartzites and sandstones interbedded with lava flows of great volume and extent. The sedimentary beds became progressively thicker as the igneous activities waned, finally terminating in the white and siliceous sandstone of the overlying formation (Upper Cambrian). The dip is even more gentle than in the Animikie.

The eruptives of the Keweenawan are divided into two divisions, the Cabotian and the Manitou.

(*a*) *Cabotian.*—The Cabotian includes the great masses of gabbro, anorthosyte, diabase, etc., which in time of origin immediately antedate the Puckwunge conglomerate. In consequence of the great extrusion of igneous material, designated as the "great gabbro revolution," large areas of the Animikie were covered with heated lavas, resulting in the fusion of considerable portions of the former. Contemporary with this flow there were also important intrusions of gabbro as sills and dikes in the unfused portions of the series.

(*b*) *Manitou.*—The Manitou series is made up of a great number of surface flows, showing amygdaloidal and brecciated partings, and alternating with beds of sandstone in the upper portion. The first of the series appear as contemporaneous beds associated with the basal, or Puckwunge conglomerate, but the greater part of the eruptives are of a distinctly later date.

III. CAMBRIAN

The eruptives of the Manitou series gradually cease and give place to whiter and more siliceous sandstones, which in turn give way without any general break to the magnesian and argillaceous limestones of the Upper Cambrian. These Upper Cambrian rocks are of comparatively slight extent and importance in the area covered by the report.

Igneous rocks.—The igneous rocks, both acid and basic, of the Archean and Taconic are regarded as originating from the hydrothermal fusion of the older rocks, mostly from the clastics. The intermediate stages may often be seen.

The igneous rocks are of three classes—granites, diabases, and quartz-porphyries. The granites are of three relative ages, two being Archean and the third Taconic. They are referred to the fused portions of a still earlier acid clastic. The diabases are also of three relative dates, in this case one being in the Archean and two in the Taconic. They are believed to have been derived from the lowest greenstones, or to occur as apophyses of the gabbro, itself a secondary condition of the greenstone. The quartz-porphyry dikes are again of three periods, one each in the Lower and Upper Kewatin, and one cutting portions of the Taconic. They are supposed to have been derived from the great quartz-porphyry mass of the Lower Kewatin, or from some later clastic.

Glacial Geology.—Besides the mass of observations relating to the crystalline rocks, there are a considerable number relating to the glacial geology of the northern portion of the state, but these observations are not systematically discussed with reference to the great problems of glacial geology.

The thirty or more maps included in the report give, in addition to the geology and ordinary topographic features, approximate contours for every fifty feet, which adds greatly to their usefulness and value. The maps are pleasingly colored and neatly executed. The volume is profusely illustrated by photographic reproductions and line cuts. The former, especially, are numerous, and though not always what might be desired in the point of clearness and appropriateness, add materially to the attractiveness and value of the report.

As one reads the report he cannot but be impressed by the great number of observations made and the mass of facts accumulated, but the disconnected and unsystematic manner of presentation, which necessarily follows from the geographical treatment adhered to

throughout the volume, detracts greatly from the value they would otherwise possess. Too much is left to be inferred, and there is always a strong liability of error in the putting together of scattered observations from various localities which the reader is obliged to do for himself in order to obtain an intelligent understanding of the questions treated.

It is proposed in the next volume of the Final Report (Vol. V), nearly half of which is already in type, to take up the systematic geology of the state, and many of the details, upon which are based the extensive changes of classification and the new conclusions regarding the problems of archean geology, are reserved for publication in this volume. It seems better, therefore, to reserve any extended criticism of the proposed changes until the full facts upon which they are based are published. M. L. FULLER.

The Ore Deposits of the United States and Canada. By JAMES F. KEMP, New York, 1900, 3d edition, rewritten and enlarged. xxiv + 481 pp. 163 illustrations.

It is with pleasure that geologists will welcome the new edition of Professor Kemp's work on ore deposits. It is to be noticed that the revision has been so complete and the additions so numerous as to bring the matter up to the date of publication and make it one of the most valuable works of its kind in this country.

Professor Kemp has undertaken a difficult task in endeavoring to embody in a single volume a serviceable text-book and a work of reference. That he has succeeded is shown in the first instance by its increased use in the colleges and in the second by a perusal of its pages.

The general plan of the work remains about the same as in the former editions. The matter is divided into two parts, the first o which treats of the general features of ore deposits, the underlying geological principles, the minerals important as ores, the gangue minerals, and their sources, the structural features of veins, the filling of veins, and the classification of ore deposits. This part of the work would have additional value, especially to the prospector and engineer, if it were illustrated a little more fully by diagrams. It is true the number of illustrations has been increased from 94 to 163, but there is

still room for more in the first part even though it should be at the expense of some of the excellent half-tones in the second part.

Part II treats of the ore deposits in detail, taking up the metals one by one, beginning with the more common useful metals, as iron, copper, lead and zinc, followed by the precious metals, silver and gold, and closing with the lesser metals. The most important of these, iron and gold, are treated more fully than the others and it is here we find the greatest changes in the new edition. This portion consists largely of a well arranged and classified review of the best literature on each locality, all the more valuable to the investigator because specific references to the original sources of information are given, thus making it a handbook and manual of reference. Field studies and personal observations in many of the leading mining centers have enabled the author not only to present the most salient features, but to supplement this from his own notes.

The features of the new edition that show the most marked changes are as follows: (1) The Lake Superior iron district is completely revised to accord with the enormous developments which have taken place; (2) the part on limonite ores has been expanded; (3) the Butte district has a new description and maps based on the excellent folio of the United States Geological Survey; (4) the same is true of the Cripple Creek and other districts in Colorado; (5) the part on the gold deposits of the southeastern states has been rewritten and enlarged; (6) a description of the Canadian mining districts, which did not appear in former editions, has been added.

T. C. H.

The Fauna of the Chonopectus Sandstone at Burlington, Iowa. By STUART WELLER. Trans. St. Louis Acad. Science, Vol. X, No. 3, pp. 57–129. Plates I–IX. Feb. 1900.

In his series of Kinderhook faunal studies, of which the present paper is the second,[1] Mr. Weller is doing a much-needed work of revision. The rocks now classed as Kinderhook mark the border line between the Devonian and the Carboniferous over an important portion of the Mississippi valley. They were, by the earlier workers, referred at times to both periods, and there was much dispute as to their proper classification and correlation. Finally Meek and Worthen

[1] For first see Trans. St. Louis Acad. Sci., IX, No. 2., pp. 9–51.

proposed the term Kinderhook to cover the beds, and named the Burlington, Iowa, section for one of the three type sections. The best known collection of fossils from Burlington has been that belonging to the University of Michigan, and known commonly as the "White collection." Descriptions of the fossils in this have been published by C. A. White, C. A. White and R. P. Whitfield, and by A. Winchell, and these descriptions have been the ones principally used heretofore in studying Kinderhook species. The descriptions were, however, in many cases unsatisfactory, and were seriously limited in usefulness by the fact that many of the species were not figured. Under the circumstances it is not surprising that the early doubts as to the age and divisions of the Kinderhook have not been altogether cleared away. Mr. Weller has made careful use of the original White and other collections, and has supplemented his data by notes and specimens taken at Burlington. He has found that the Kinderhook includes seven distinct faunal zones, and in the series of papers now being published he is describing and figuring the fossils from these individual zones. It proves that certain of them have strong Devonian affinities, while others are to be assigned to the Carboniferous. Much of the confusion has come from the failure to distinguish the individual bed from which the species were collected. In the case of the Chonopectus sandstone the brachiopods are, for the most part, strongly Carboniferous in aspect. The pelecypods, gasteropods, and cephalopods, are predominantly Devonian as is the larger number of the total of 81 species recognized. The author regards this, however, as a probable instance of the persistance into Carboniferous time of certain favored Devonian forms. The other view, that these are the earliest and initiatory Carboniferous forms appearing in time properly Devonian, is not, however, as yet, excluded.

As a whole the paper is one of wide interest and value, and will prove very suggestive and useful.

H. F. B.

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THE

JOURNAL OF GEOLOGY

APRIL—MAY, 1900

EDWARD ORTON.

EDWARD ORTON, born Deposit, Delaware county, N. Y., March 9, 1829, was descended from old New England stock on both sides of the house. His father, Thomas Orton, a Presbyterian clergyman, whose memory is still cherished in northwestern New York, moved to Ripley, N. Y., on the Lake Erie shore soon after his son's birth. There the son grew up amid an agricultural population, sharing their work and their amusements and gaining an intimate knowledge of their needs which affected his whole course in life. As a lad, he is said to have been somewhat shrinking and sensitive to ridicule ; always courteous, always considerate of the feelings of others and sternly conscientious.

His father prepared him for college and, at what appears to us the early age of fifteen, he entered the Sophomore year at Hamilton with the class of 1848. The college course of fifty years ago was narrow, carefully avoiding more than very superficial treatment of the inductive sciences and dwelling chiefly upon classics, elementary mathematics and certain philosophical studies. Edward Orton pursued the course faithfully, though there was little in it attractive to one of his tastes, and at graduation he had a well trained mind with a good stock of such

knowledge as the course afforded. The careful drill in linguistics was that from which he derived most profit, and it was in evidence throughout his writings.

After teaching for one year at Erie, Pa., he entered Lane Theological Seminary at Cincinnati, O., to prepare for the Presbyterian ministry, but, before the year ended, his eyesight failed and he gave up study to become clerk on a coasting vessel sailing to Florida. The autumn of 1851 found him in the Delaware Literary Institute at Franklin, N. Y., where, as instructor in Natural Sciences and German, he was expected to teach any subject offered in the very liberal curriculum. The hours were long and the classes numerous, but his enthusiasm infected the pupils, who accompanied him on long field excursions for study of botany and geology. The next year was spent at Harvard in the study of chemistry and botany, after which another year was spent in successful teaching at Franklin. He then entered Andover Theological Seminary to complete preparation for the ministry. He was licensed in 1855, and soon afterward was ordained to act as pastor of the Presbyterian church at Downsville, Delaware county, N. Y.

He resigned his charge in June 1856, to become professor of Natural Sciences in the New York State Normal School at Albany, N. Y. There he had access to the State Museum and was associated intimately with the strong men on its staff. His life in the Normal School was ideal, and his studies in the State Museum were what he had longed for. Everything appeared to be conspiring to his benefit and to great usefulness in his chosen work.

But, early in his theological studies, doubts had arisen in his mind respecting some tenets of the church and these, it is believed, had something to do with the abrupt termination of his studies at Lane seminary. These doubts were made stronger by the surroundings at Harvard and he undertook the study at Andover with an earnest desire to remove them. It contributed to that result at least so far as to render them subordinate and to permit him to assume the Presbyterian ministry. After he

went to Albany, however, the doubts returned and, increasing in intensity, became convictions so strong that he could not consent to remain in connection with his denomination. To avow his opinions, which, being practically those of the Unitarian church, were very unpopular at that time, would involve not only separation from his church affiliations but also loss of his position in the Normal School; for, though that was a state institution, a public discussion of his views might have alienated an influential portion of the community if he had retained his chair. To many men the temptation would have been serious; no longer in the active ministry, he could have concealed his opinions and could have withdrawn from his denomination without discussion, in this way retaining his position, so important as affording not merely support but also opportunity for thorough study. But his sturdy integrity knew nothing of casuistry; he could not be guilty of even negative hypocrisy. He avowed his opinions, gave up his position, lost his income but gained the abiding respect of his associates, both in church and in school.

The only opening immediately available was the principalship of an academy at Chester, Orange county, N. Y., which he accepted and held for six years, fitting young men for college and lecturing on scientific subjects whenever he had opportunity. His duties left little of spare time, but what he had was utilized in study of such natural phenomena as the region presented, especially those connected with agricultural interests — an admirable preparation for his future work.

Professor Orton's intimate friend at Chester was the Rev. Austin Craig, pastor of an independent church near that place. In 1865, Mr. Craig was chosen acting president of Antioch College in Yellow Springs, O., and Professor Orton was made principal of the preparatory department. Soon afterwards he was appointed to the chair of Natural Sciences. He proved himself so wise, so tactful, that, in 1872, he was called to the presidency of the college. But he was reluctant to assume the responsibility and wrote to Dr. Newberry, with whom he was associated on the State Geological Survey, asking advice. In a

manly way, without self-depreciation, he gave his reasons for hesitation. Dr. Newberry's emphatic reply was that a man's friends usually understand him better than he does himself. The position was accepted and the event proved that his friends were right. His administration was marked with such vigor, and at the same time with such good judgment in dealing with men both inside and outside of the college that he soon became known throughout the state. When the State Agricultural College was organized in 1873, he was made president, and professor of geology.

The organization of a state college with the agricultural land grant as the endowment was a task whose magnitude might well appal a thoughtful man. Local colleges dreaded a powerful rival; farmers demanded a curriculum suited to their conception of agriculture; lovers of the old methods of education feared too much of application to everyday matters; "practical" men insisted that little attention should be paid to theory, and that "practice" should be supreme; politicians saw in the new institution an opportunity to strengthen themselves by grants of positions; while not a few thought the gift from the national government might prove to be another Pandora's box. But happily, the first board of trustees proved to be men of excellent common sense; they recognized that the work of organization, if it were to be done well, would have to be done by one familiar with educational needs, and that without interference. The work was left to President Orton, whose studies of agricultural conditions, carried on so assiduously for many years, supplemented by his work as teacher, professor, and college president, had rendered him familiar with the complex problems involved. The curriculum was planned, not with a view to bringing the greatest number of students at the earliest moment, but with a view to the advantage of the state and of higher education. The wisdom of this course was soon manifest, for, though the number of students was small during the first year, it increased so rapidly, and the scope of the institution was expanded so greatly that in 1878 the name was changed to the Ohio State

University, the older title being recognized as no longer applicable.

But executive duties were never attractive to him; they interfered with his work as a student. Again and again he asked to be relieved from the presidency, but not until 1881 did the trustees feel that the institution could bear a change. At that time, when the university was established and its policy determined, they yielded to his urgent request. Thenceforward he devoted himself to the chair of geology. With characteristic wisdom he became merely a professor, and apparently forgot that he had been president. One finds no room for surprise at the respect and affection with which his colleagues regarded him.

Professor Orton's love for natural science was distinct early in life, but it always leaned toward application to the benefit of somebody, for, in the proper sense of the term, he was a utilitarian. As soon as he was settled at Yellow Springs he began to study the deposits so well exposed in that neighborhood and quickly gained, as no others had done, a thorough understanding of their relations. His collections of fossils, made wisely and scientifically, proved of great service to paleontologists; he delivered lectures upon scientific subjects, accurate, yet devoid of technical language—lectures of a type little known at that time; he was sought as a speaker among farmers, in village lyceums, and at teachers' institutes. Within two or three years he had become the scientific authority for southwestern Ohio. When the geological survey was organized in 1869 he was appointed one of the two assistants, with the southwestern portion of the state as his district.

At that time there were few geologists. The old surveys had ended in the early forties; a few attempts had been made to organize new surveys, but only that in Illinois had attained real success. Some students had gained experience on the government expeditions in the far West, but of trained geologists there were barely a score. Professor Orton belonged to the generation beginning work immediately after the Civil War, but

he had done much more than most of those within reach, so that his assistance was sought eagerly by Professor Newberry on the Ohio survey. He began the investigation of the Silurians and Devonian, which covered most of his district; but some of the higher deposits were reached and he was compelled, under instructions from the director of the survey, to pass beyond the limits of his district and take up discussion of problems which others thought were peculiarly their own. In all respects he was the strong man of the corps. Painstaking and exact in observation; scrupulous in statement; cautious in speculation, he was called upon many times to render decisions in localities respecting which the reports were in conflict. When Dr. Newberry resigned after the publication of Volume III, Professor Orton was placed in charge. The work was in a peculiar condition. At the beginning of the survey the aids were mostly young men with little field experience, this of necessity, as trained geologists could not be obtained. Some of the work done by those observers was very defective, as the writer, one of the inexperienced aids, can testify; county reports, written independently, were not always accordant; even the general section was unsatisfactory, for identifications had been made with horizons in Pennsylvania beyond an area which had not been studied in detail. Prior to Professor Orton's appointment as director, the work along the state line had been completed for the Pennsylvania survey, and the results did not agree with those presented in the Ohio reports. All this can be said without in any wise reflecting upon those connected with the Ohio survey at the beginning, for every man labored conscientiously to the best of his ability, according to the knowledge then available. Their work, though erroneous in some of the details, resulted in great advantage to the state and in important contributions to geology.

But Professor Orton, in taking up the matter anew, saw that these errors, though apparently of slight economic importance, might lead eventually to serious results, and he set himself to correct them. How difficult the task was few can understand,

but the outcome was that masterly presentation of the whole Carboniferous series of Ohio, in which the relations and variations of every prominent bed as it occurs within the state and in adjacent portions of other states are presented in such fashion as to make the discussion distinctively one of the best yet contributed to Appalachian geology. In this the awkward task of correcting the errors of those who had made the original observations is performed with a delicacy rarely equaled. Good work is noted, but errors are referred to in such a way that to discover whose they are would require more labor than anyone would choose to expend. Indeed, the reader is inclined to believe that every error in observation was due to too earnest desire to do faithful work—which is more than half true.

During Professor Orton's term, the petroleum interests attained great importance; the origin of the oil, the mode of occurrence and the laws regulating the flow were studied with great care. At the same time and with equal care problems relating to natural gas were investigated. Professor Orton was recognized quickly as an authority upon all matters respecting petroleum and natural gas, whether scientific or technical, and he was called upon by the Kentucky, New York, and United States surveys to prepare elaborate reports; so that his writings will be the standard reference for years to come. His studies led him to issue appeals to the people of Ohio urging care in husbanding their resources; but these were not received in the spirit in which they were offered. He had the melancholy satisfaction of seeing his forebodings justified by the event. The distribution of fire and pottery clays, studied in reconnaissance by some aids on the Newberry survey, was taken up systematically and a complete investigation made under his direction by his son, who has succeeded him as director of the survey. Building stone, iron ore, glass sands, and other materials of economic interest, all received careful study. Professor Orton's reports prove the intimate relation between pure science and industrial growth.

Throughout his career, while ever anxious to improve the condition of the community by inducing men to utilize the discoveries of geology, he was ever on the alert to advance the

cause of pure science; for he always maintained that only by its rapid advance can the economic side find advance. The debt of geology to Edward Orton is very great, far greater than we are apt to think, for, in his writings, he effaced himself and often gave credit to others for what was rightfully his own. While he did much for science, he did even more for his state, many of whose industries owe the present success very largely to his efforts—efforts due solely to his anxiety for the public welfare and made without expectation of reward, pecuniary or otherwise.

But Professor Orton was more than teacher and geologist. With burdens of exacting character in the university and in the state geologist's office, he found time and opportunity for services in other directions. The city of Columbus lay near to his heart and he was indefatigable in efforts to advance its interests. He was always ready to aid in any organization looking to the public good; even the state's prisoners were objects of his care for many years. He did not neglect his duties as a citizen, but labored to secure proper candidates for political offices. His time belonged to others; he never felt himself his own.

Professor Orton was always impressed with the exceeding value of time, with the importance of utilizing moments. He was as one intrusted with an estate to be improved to the last degree before the owner's return. Every day's work was done as though that were the only day. Such conscientious devotion gave authority to his statements. Whenever his conclusions proved to be erroneous, the error was regarded as merely additional proof of the limitations of the human mind. With this spirit, whatever he did, whatever he wrote, was brought modestly as a contribution to the growing edifice of knowledge and was offered with such self-forgetfulness that recognition of its merit and of indebtedness to him appeared often to be a matter of surprise rather than of gratification. Honors came to him unexpectedly but they came often.

But while thus sensible of responsibility, Professor Orton never carried a burden. He enjoyed the companionship of his fellows; he had a keen sense of the humorous, but his humor never took the form of sarcasm; no sting was attached to any word

that cropped from his lips or pen. Many times he was compelled to assert himself forcibly, even indignantly, but no bitterness could be discovered in his rebukes. He was the incarnation of integrity ; a friend who never wavered.

Little wonder that when he died, the loss to science was less regarded than was the personal loss which was felt by so many in all stations and in all callings; that the man was remembered more than a student. Those of us whose acquaintance with him began thirty years ago became attached to him in such fashion that we rejoiced when good came to him, not asking why it came but gratified that it had come to so true a man. The man has gone and now we think often of the student who deserved to the full, and more, all of the recognition which his work received. We can lay a double tribute upon his grave, one to the man whom we loved and one to the geologist who solved so many perplexing problems.

In the midst of his usefulness, in 1890, Professor Orton was stricken by paralysis which rendered his left side useless. Crippled, with his work incomplete, it seemed as though his life was to pass away in darkness. But his mental powers were unaffected and he recovered strength to such a degree that he continued to work until within a short time previous to his death. In 1899 his health gradually declined. When the American Association for the Advancement of Science met in Columbus last year, he gave an address, so much longer and so much more important than that expected from an incoming president, as to lead some to suppose that he did not expect to live until the meeting of this year. Be that as it may, the address was his last word to his fellow-workers in science. He grew perceptibly weaker after the meeting closed and, on October 16, 1899, he passed away suddenly and without pain.

Professor Orton married, in 1855, Mary M. Jennings, of Franklin, N. Y., who died in 1873. The four children of this union still survive. He married Anna Torrey, of Milbury, Mass., in 1875, who, with their two children, survives him.

John J. Stevenson.

THE GRANITIC ROCKS OF THE PIKES PEAK QUADRANGLE[1]

GENERAL RELATIONS

Few natural features in the west are better known by name and form than Pikes Peak, which has served so often as a goal for the pioneer and traveler or as a fitting subject for the photographer and artist. Its prominence arises from its position as the landmark first seen by the traveler moving westward, and from the abruptness with which it rises 8000 feet above the plateau at Colorado Springs.

Moreover, the rapid developments in mining at Cripple Creek and the papers[2] that have recently appeared on the subject have increased the interest in the area and have directed thought to its geology.

In the present paper it is proposed to give a summary of the results obtained from a field and detailed laboratory study of the

[1] Published by permission of the Director of the U. S. Geological Survey.

The field work for the present paper was carried on by the writer while a field assistant in the party of Mr. Whitman Cross who directed the work and suggested the problems to be studied. Many of the specimens were collected by Mr. Cross, and his field notes have been used freely. For the constant willingness to give assistance and the freedom in the use of notes, the writer wishes to express his gratitude to Mr. Cross, who furnished the opportunity to study so extensive an area.

[2] Whitman Cross: Intrusive Sandstone Dikes in Granite, Bull. Geol. Soc. of Am., Vol. V., 1894, pp. 225–230; Geology of the Cripple Creek Gold Mining District; Proc. Colo. Sci. Soc., June 4, 1894.

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E. B. Mathews: The Granites of the Pikes Peak Area, Bull. Geol. Soc of Am., Vol. VI, 1894, pp. 471–473.

Whitman Cross and R. A. F. Penrose, Jr.: Geology and Mining Industries of the Cripple Creek District, Colo. Part I, General Geology, Whitman Cross; Part II, Mining Geology, R. A. F. Penrose, Jr. Sixteenth Ann. Rept. Dir. U. S. Geol. Surv., II, Washington, 1895, pp. 13–217.

W. O. Crosby: The Great Fault and accompanying Sandstone Dikes of Ute Pass, Colorado, Science, new series, Vol. V, 1897, pp. 604–607. Archean Cambrian Contact near Manitou, Colorado, Bull. Geol. Soc. of Am., Vol. X, 1899, pp. 141–164.

granular igneous rocks comprising the summit of Pikes Peak, and the area to the west of it, included within the Pikes Peak quadrangle of the Geologic Atlas of the United States. The field observations were made during the seasons of 1893 and 1894, and the laboratory studies during the succeeding winters.

The quadrangle studied contains, approximately, 930 square miles and embraces the greater portion of the southern termina-

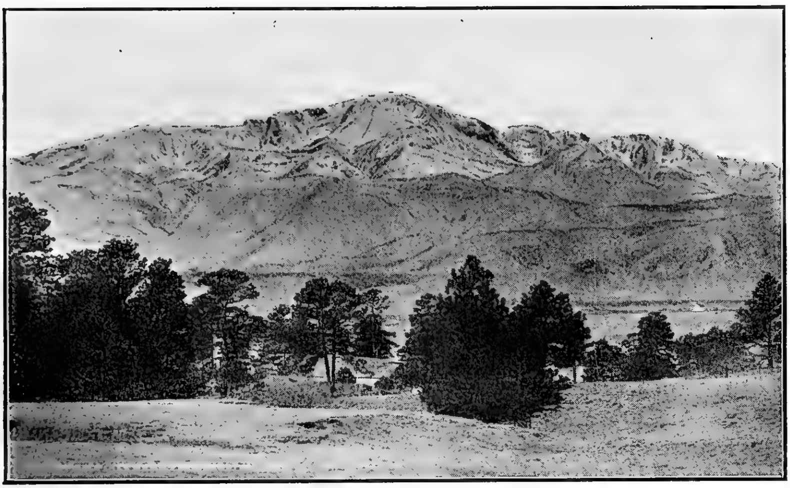

FIG. 1.—Pikes Peak seen from the plain.

tion of the Front or Colorado range in its *en eschelon* ending east of the Royal Gorge of the Arkansas. The topographic features of the area are the mountain massif on the east, rising rapidly as shown in Fig. 1, from the level of the plateau to the height of 14,108 feet above the sea. Westward from the summit the slope is much gentler, as shown in Fig. 2, to the somewhat dissected plateau of Cripple Creek and Florissant, drained on the north by the tributaries of the South Platte River and on the south by Oil Creek and its tributaries which drain into the Arkansas River The divide between these two drainages does not include the summit of Pikes Peak but passes somewhat to the north and west of the mountain mass.

The rocks of the region represent massive and schistose granites, metamorphic schists, remnants of formations belonging to the Algonkian, Cambrian, Silurian, Carboniferous, Jura-trias, Cretaceous, and Eocene periods, and numerous igneous rocks including basic breccias, massive andesite, andesite breccias, trachyte, rhyolite, phonolite, and nepheline-syenite.

The granites and gneisses of the Rocky Mountains have generally been regarded as part of the Archean complex, but it has been shown[1] that within the main granitic masses of the Pikes Peak area there are many included fragments of quartzite and of schists that show their derivation from sandstones through induration and metamorphism. These sediments are regarded as of Algonkian age, and the granites cutting these strata are accordingly either Algonkian or early Cambrian. It is deemed most in harmony with the facts in the case to refer the granitic eruptions to the late Algonkian period.

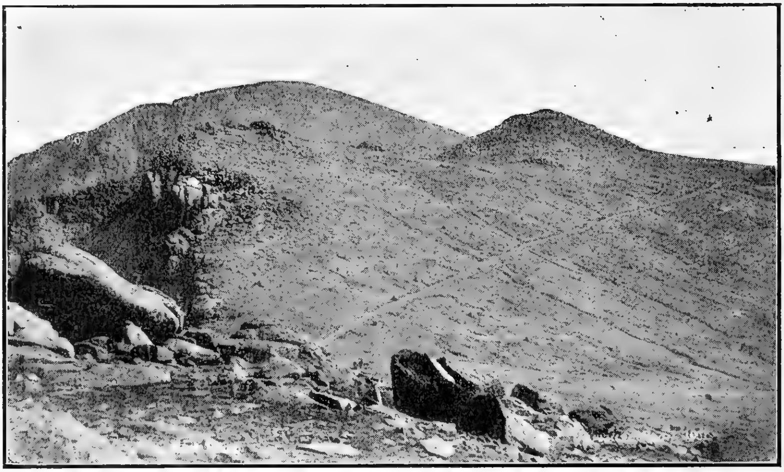

FIG. 2.—Pikes Peak from carriage road (13,000), (showing gentler western slope).

The schistosity in the gneisses was produced prior to the Upper Cambrian and this fact, together with the assumed age of the granitic eruptions renders it probable that the squeezing

[1] Pikes Peak Folio No. 7, Washington, 1895.

of the granites is due to earth movements which preceded the Cambrian.

The following pages treat almost exclusively of the granitic rocks of the area.

ROCK TYPES

The greater portion of the area studied, as shown by the accompanying sketch and the more complete map in the folio of the Geologic Atlas,[1] is occupied by granites, gneisses, and associated schistose rocks which form an undulating platform underlying the later formations. The prevailing composition of this complex is that of a typical granite with the addition of a small amount of fluorine, while the characteristic mineral constituents remain the same over an area of more than a thousand square miles, notwithstanding the fact that the exposures are representative of bodies intruded at different periods, and crystallized under somewhat different conditions. The granites are light colored, usually pinkish, holocrystalline aggregates of feldspar, quartz and biotite with occasional hornblende and fluorite. The individual components vary in their size and relative abundance and in the perfection of their crystal form ; but in almost every instance the feldspar is larger, more abundant and somewhat better formed than either the quartz or biotite. These variations in the manner of aggregation and in the size of the constituent minerals give rise to well-defined types of granite which were distinguished and plotted in the field.

Although some sixteen varieties of granite were distinguished during the mapping, later study has shown that all masses of prominence may be referred to one of four clearly defined types which have been named,[2] the Pikes Peak, the Summit, the Cripple Creek, and the Fine-grained types respectively.

PIKES PEAK TYPE

A large part of the area of the accompanying map is occupied by a single type of granite, called the Pikes Peak type, from its

[1] Geological sheet. Pikes Peak folio, No. 7, Washington, 1895.

[2] Bull. Geol. Soc. Am., VI, 1894, pp. 471–473.

prominence in the constitution of the Pikes Peak massif. This type is characterized by the relatively large size of its feldspar and quartz grains and its tendency to form conspicuous feldspar phenocrysts that often attain a diameter of several inches.

The fresh, unaltered granites of this type are coarse-grained aggregates of quartz, perthitic feldspars, and biotite with occa-

FIG. 3.—Pikes Peak type of the granite.

sional accessory hornblende or fluorite and microscopic apatite, zircon, titanite, magnetite, rutile, hematite, limonite, epidote, and allanite.

The grain varies widely from extremely coarse where the feldspar phenocrysts are six inches long to the more normal granite in which the length of the feldspar grains is little more than a quarter of an inch. The usual diameter for the feldspar is about half an inch, and for the quartz, a quarter of an inch to an eighth of an inch. The biotite areas, although generally smaller than the quartz grains, are sometimes a half inch in width. (Fig. 3.)

The texture of this type presents all grades of transition from that in which the feldspar is only slightly larger than the quartz to one in which the feldspar stands out in large, imperfectly formed porphyritic crystals.[1]

The areal distribution of the rocks showing such increase in the development of the feldspar is not clearly defined, although there is a faint suggestion of a concentric wrapping about the lower slopes of Pikes Peak.

A mechanical separation shows the constituent minerals of the Pikes Peak type to be in the following proportions by weight:

Quartz	33.4
Microcline	53.3
"Biotite"	10.7
Oligoclase	2.6
	100.00

The "biotite" includes all of the minerals with a greater specific gravity than 3.0.

The quartz occurs in large irregular or oval, colorless or smoky grains distinctly outlined against the feldspar and biotite towards which it is usually xenomorphic. In one instance, a basal section of quartz presented three systems of cracks intersecting at 60° representing an imperfect rhombohedral cleavage probably due to mechanical deformation. The extinction ranges from completely simultaneous to mottled or undulatory.

The inclusions observed are arranged according to one of three ways. (1). The small and irregularly shaped inclusions occur either in long thin lines parallel to the rhombohedron, in broader unoriented zones, or irregularly massed in definite parts of the quartz individuals. (2) The small, somewhat rectangular cavities are arranged in indistinct lines parallel to their longer directions but not related to the crystallographic directions of the quartz. (3) The fine, hair-like "needles" have a linear arrangement and seem to occur when the other inclusions are

[1] The coarse-grained granite in which the feldspar phenocrysts are large and generally well formed, is sometimes called the "Raspberry Mountain granite," from its conspicuous development on that mountain.

fewer and more evenly disseminated through the quartz. The mineral nature of the last group could not be determined. The individual inclusions are minute apatites and zircons, hematite plates and magnetite.

Quartz occurs in some of the slides as an inclusion in the feldspars. It is probably secondary in both the microcline and the oligoclase, though in the former it may possibly be original. With the feldspar quartz forms micropegmatitic intergrowths in the more weathered and crushed specimens, but this is lacking in the fresh, unaltered rocks.

The feldspars in the Pikes Peak type vary in size, shape, composition, and age. The color is generally pink or gray, or both where there is a zonal structure. The most important feldspar is microcline perthitically intergrown with albite. This always shows the characteristic "microcline twinning" in all sections inclined to the brachypinacoid. The mesh of the rectangular grating is very small in all those instances which are regarded as original. In the small secondary flakes, however, the mesh is much coarser.

The inclusions within the microcline are albite, quartz, oligoclase, biotite, and the earlier products of crystallization. The most abundant are perthitic pegs of albite, and their disk-like cross-sections. The former lie approximately parallel to a steep positive macrodome in a plane normal to the edge (001) (010). The small round disks may easily be confused with the pellucid quartz from which they can be separated only by the use of converged polarized light.

Oligoclase is only of subordinate importance in the Pikes Peak type where it occurs in small light gray-green anhedral areas with characteristic polysynthetic twinning, lamellae showing on the base an extinction angle of $2°–3°$. The inclusions lie close together near the center of the plagioclase plate and are surrounded by a zone of clear feldspar from which they are more or less sharply defined. The cause of the presence and position of these inclusions is not known. The usual explanation based on the increased basicity and consequent instability of the core

may apply, but the same phenomena may be the result of variations in the conditions during solidification. With the less viscous state of the magma during the early stages of solidification the supply of material is abundant and the growth rapid. The imperfections in crystallization increase with the rate of consolidation, through the inclusion of interpositions and the imperfect filling of space. As the magma on cooling becomes more viscous, thereby decreasing the easy transfer of material and the consequent rate of growth, the molecular arrangement of acquired material on the growing crystal is more perfect in its outer zone. This difference in homogeneity between the core and exterior is sufficient to develop a tendency towards molecular rearrangement in the interior whenever the physical conditions are changed. The sharpness of the limits is determined by the growth lines as in twinning lamellae or zonal structures.

Biotite occurs either as individual flakes or small aggregates presenting the appearance of single flakes to the unaided eye. The mica is strongly pleochroic in brown and yellow, and has an optic angle of 10°. Since the plane of the optic axes was found in several instances to lie perpendicular to the leading ray of the percussion figure, much of the mica is probably anomite.

Hornblende is relatively rare in all the granites of the area. It occurs most often in the Pikes Peak type associated with biotite and titanite. The amount of mica decreases somewhat when hornblende is present, while an increase in the latter is generally accompanied by an increase in the titanite. The hornblende-bearing granites occur in somewhat circumscribed areas below Green Mountain Falls, along the railroad east of Florissant and in the hills east of Lake George.

The accessory minerals enumerated on a preceding page occur in varying amounts. They are usually in small crystals, and belong to the earlier stages of consolidation. Titanite and fluorite are of especial interest, since the former has been found only in this type while the latter is rare, though abundant in the Summit type. Neither presents any mineralogical peculiarities.

Among the alteration minerals resulting from the weathering or metamorphism of this type are epidote and sericite associated with the feldspar; and calcite, chlorite, and muscovite accompanying the biotite.

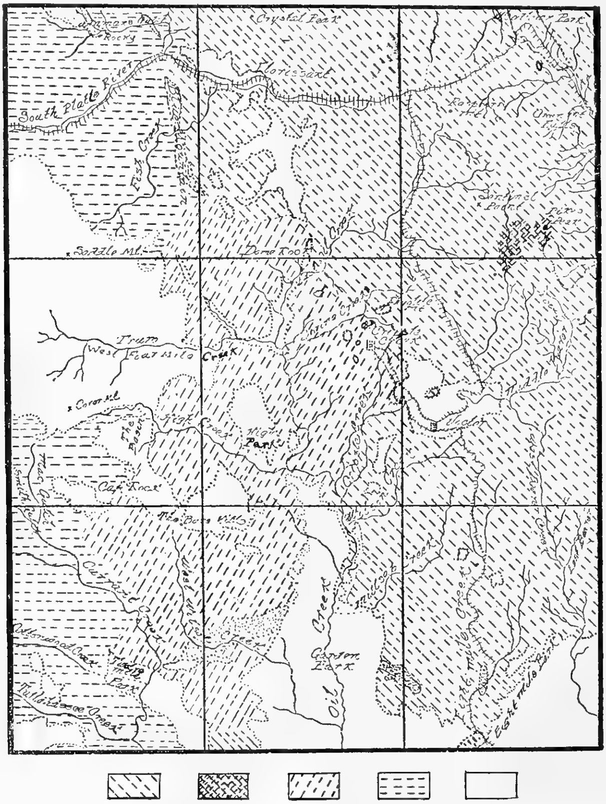

FIG. 4.—Sketch map showing the distribution of the various types of granite occurring in the Pikes Peak quadrangle.

Distribution.—The granites of this type extend northeastward from a sinuous line drawn through the lower slopes of Blue Mountain, Dome Rock, Cripple Creek, and Oil Creek Canyon to the southeastern border of the Pikes Peak Quadrangle. (Fig. 4) The limits beyond the area of the Quadrangle have not been

examined, but are shown in a general way in the maps of the early Hayden survey some miles to the north and east of the Pikes Peak area. Similar rocks have been described from the Platte Canyon in Jefferson county for the Educational Series of the United States Geological Survey.[1]

In its distribution the Pikes Peak type, in the contact with each of the three remaining types distinguished, appears as the older type. It is therefore the oldest granite in the area. The best place for studying the age of this type is in the region about the summit of the massif. Here it is cut by many dikes of the Summit type, which seem to radiate from the central eminence. The actual contact between the two granites is rarely evident in this area, however, as the blocks of the Summit type have formed a slide slope which masks the more easily disintegrating coarse-grained granite. Wherever the contact is observable, as in Wilson Creek southeast of Cripple Creek, the finer rock is seen to cut the coarser. The relations with the Cripple Creek type are poorly defined, as the exposures almost always show small masses of metamorphosed sediments at the immediate contact. The greater age of the Pikes Peak type is shown, however, in several exposures, as, for example, on the north side of Caylor Gulch at an elevation of 8600 feet, where a fine-grained saccharoidal granite of the Cripple Creek type cuts the coarser schistose granite which is correlated with that of the Pikes Peak type.

Weathering.—The processes and results of weathering in the Pikes Peak type are among its most characteristic features. The light pink color becomes darker on exposure and passes into a deep red through a bleaching of the biotite and the subsequent staining of the feldspars and quartz with the liberated iron oxide. The physical changes due to weathering are, however, more manifest. The rock disintegrates before it is decomposed. For this reason the hills are rounded and covered with granite gravel when the disintegrated material remains, and rugged or steep where the débris has been carried away. Fig. 2 gives a view of

[1] Bull. U. S. Geol. Surv., No. 150, Washington, 1898, pp. 172–177.

Pikes Peak from the northwest at an elevation of 13,000 feet, which well illustrates this difference. On the west the mountain slopes with smooth rounded outline into the drainage of Beaver Creek, while on the east the descent is precipitous in ragged cliffs, sometimes resembling huge cyclopean masonry. Counteracting this physical disintegration are chemical changes which

FIG. 5.—Disintegrated bowlder of granite showing surface hardening and disintegration beneath.

protect the rock at first, but ultimately, in conjunction with the physical forces, accelerate the rate of rock-weathering.

The effect of weathering extends for a distance of two or three feet beneath the surface of the exposed rocks. On the exterior there is frequently a dense crust, or glazing, rarely more than half an inch thick, covering a second zone several inches wide, in which the mineral are stained with iron and loosely held together. Beneath this zone the rock is often so incoherent that it seems ready to fall to pieces. The crumbling mass, in turn, passes gradually into the solid rock. Fig. 5 represents a bowlder with the coating on the surface and the disintegrating rock beneath. In this view the upper surface appears

more resistant to the weathering agencies, while the friable rock beneath has fallen away leaving the crust as a projecting edge. Such a crusting over friable material often leads to fantastic shapes, as represented in Fig. 6. The final result of the weathering is the formation of a thick coating of talus and granite gravel, composed of relatively fresh fragments of the rock and its mineral constituents.

FIG. 6.—Fantastic forms due to weathering and surface hardening.

SUMMIT TYPE

The rocks of the Summit type show a very constant texture closely allied to that of granite-porphyry (Fig. 7). They are composed essentially of small gray feldspar phenocrysts embedded in a finely granular aggregate of hypidiomorphic, quartz, smaller feldspars, biotites, and minute grains of fluorite. Microscopic zircon, magnetite, hematite, and micropegmatitic intergrowths of quartz and feldspar are also present.

When fresh the color of the rock is purple, ranging from purple-violet to carmine-purple.[1] As the rock becomes weathered the color becomes less pronounced and fades to light neutral gray and brown.

The minerals composing the Summit type differ very slightly from those described under the preceding type. Quartz is more

[1] Nos. 23_p and 26_s of Radde's International Farben scala.

abundant and in smaller areas, and the numerous fine grains in the groundmass are free from much included matter. The larger individuals, however, present the broad zones of inclusions noticed in the preceding type. The porphyritic feldspar is microcline, as in the first type, but here the perthitic intergrowths of albite are much less common. The microcline also

FIG. 7.—Summit type fine grained granite-porphyry.

composes much of the groundmass where it fills the interstices between the grains of quartz. Untwinned clear grains of feldspar, probably orthoclase, are also present in the groundmass in considerable abundance. Oligoclase showing fine twinning lamellae is more poorly developed than in the Pikes Peak type. All of the feldspars are much clouded with alteration products, especially by sericite and some iron compound, either hematite or limonite. The abundant development of micropegmatitic intergrowths of quartz and microcline in this type is noteworthy, as these are practically wanting in the fresh Pikes Peak granite. The

quartz occurs in small oval, or irregular, disks which have the same orientation over considerable areas of the feldspar. Although these disks may lengthen out, they do not have the branching-radial arrangement characteristic of some of the other occurrences.

The biotite occurs in flakes without good crystal outline, and locally shows quite an advanced stage in the alteration towards chlorite and lenses of quartz formed between the foliae. The same slide may show perfectly fresh pieces of biotite associated with that which has become thoroughly chloritized. Unlike the mica of the Pikes Peak granite, the biotite of the Summit type is of the first order with the plane of the optic axes parallel to the principal ray of the percussion figure.

Hornblende, titanite, and magnetite are practically wanting in this type, although a few fresh irregular grains of the latter were noticed in a single slide.

The most characteristic mineral in the Summit type is fluorite. This is present in every section but one made from the Summit granites. It is commonly in small irregular areas and rarely in well-defined crystals. When the crystal contours are evident the little squares suggest either cubes or octahedrons. The mineral is especially characterized by a highly perfect octahedral cleavage which is well developed in the larger areas, but is lacking in the minute crystals. The anhedral areas are clear and either colorless, purple, faintly pink, or green. The pigment is unevenly disseminated through the grains, and seems to be more intense about inclusions than in the clearer parts of the mineral. Between crossed nicols the areas remain perfectly isotropic, and in ordinary light the mineral shows a shagreened surface corresponding to its very low index of refraction. All of the properties enumerated are characteristic of fluorite. The view that this is fluorite is corroborated by the high percentage of fluorine in the bulk analyses and the presence of fluorides in the veins of adjacent areas.[1] Microchemical tests were made, but failed to give conclusive results.

[1] E. g., St. Peter's Dome (Bull. U. S. Geol. Surv., No. 20), and Cripple Creek (Sixteenth Ann. Rept. U. S. Geol. Surv., II, 1895).

Although the gold ores and the fluorite are sometimes intimately associated in the mining area near Cripple Creek, no indications of gold, sulphides, or tellurides were seen in any of the sections of the Summit type.

Distribution.—The rocks of the Summit type are confined to a small area about the Summit and down the western slope of the highest part of Pikes Peak, and the relation between them and the other granites is only seen in a few places. On the main peak there seems to be a system of radiating dikes, but the contacts are not well exposed in place. In Wilson Creek canyon and near the intersection of Spring Creek with the Cripple Creek-Florissant road there are dikes of granites correlated with that of the Summit type which clearly cut the older Pikes Peak granite.

Towards the other granites this type seems to be older, since it is never found in them, while they occur in small masses within its areas.

Weathering.—In the manner of their weathering the rocks of the Summit type show many differences from those of the Pikes Peak type. Instead of disintegrating into massive, rounded bowlders and coarse gravels like the latter, the granite-porphyry breaks up into smaller angular blocks, as illustrated in the familiar views of the Upper Station of the Pikes Peak Railway. These blocks and many of the ledge exposures, moreover, have a glazed crust similar to that observed on bowlders of the Pikes Peak type. What the nature of the process is which produces this surface was not determined in the somewhat hasty survey of the upper portions of the mountain, although the natural surroundings suggest three possible agencies for such polishing, viz., blown sand, ice, and chemical action. The smoothness of the surfaces and the occurrence of polished surfaces in sheltered hollows is against any polishing by sand, while the presence of a crust on somewhat recently formed bowlders and steep slopes, and the absence of glacial striae militate against any explanation based on ice action. The thickness of the shell and the decayed character of the interior, on the other hand, seem to indicate that

this crust is due to chemical action. The great diurnal changes in temperature, the dryness of the air, and the direct action of the sun tend to promote rapid changes in the amount of moisture present, and this in turn would cause alternations of solution and precipitation. Throughout the nights and the winter seasons the rocks receive by capillary action a considerable supply of moisture which during the day and the summer would take some of the material from the interior and carry it to the surface, where there would be rapid evaporation and precipitation. Such action must be slow, as the material carried out is but slightly soluble even under favorable conditions; and yet this very insolubility helps in the final result by rendering at least a portion of the deposited material independent of the rains. The increased amount of silica in the crust seems to corroborate this hypothesis of chemical action.[1] The formation of a crust on the rhomboidal joint blocks, together with the closeness of grain of the rock accounts in great measure for the angularity of the blocks strewn over the summit, and may in part account for the present topographic preëminence of this portion of the massif.

CRIPPLE CREEK TYPE

The granites grouped under this title, compared with those of the preceding types, appear finer than those of the Pikes Peak type and more evenly grained than those of the Summit type. They are finely coherent saccharoidal aggregates of microcline, vitreous quartz, and glistening biotite with occasional microscopic individuals of zircon, hematite, magnetite, and apatite. When phenocrysts are present they are usually microcline, although in an exposure at the Placer Mill northwest of Cripple Creek, broad glistening flakes of biotite are porphyritically developed.

The most prominent constituents are small, rectangular crystals of fresh pink microcline which occasionally reach the length of half an inch (Fig. 8). The twinning network is medium coarse

[1] CROSBY (Merrill, Rock Weathering, p. 255) suggests also the deposition of iron oxide.

and therefore differs from that of the other types. This mesh, however, is not as coarse as that in the smaller, probably secondary, microclines present in the same slides, and in the altered granites more fully described elsewhere. Perthitic intergrowths with albite are not prominent in the majority of the sections, but are very abundant in the slides representing some of the

FIG. 8.—Cripple Creek type of the granite.

granites from the vicinity of Seven Lakes. The microclines of this locality are twinned parallel to the basal pinacoid, according to the Manebach law, and differ only in size and occurrence from the large and beautiful amazonstone and orthoclase so well known from this area. The perthitic lamellae meeting at the composition face (001) form an angle of 147° and in each case lie a few degrees from the vertical axis in obtuse β (parallel to a steep positive orthodome).[1]

[1] In color and texture this rock resembles the well-known granite from Red Beach, Me., described in the Tenth Census, and it is probable that if similar rock can be found where the conditions of quarrying and transportation are favorable it will prove of economic interest.

The irregularly oval grains of quartz composing from one seventh to one quarter of the rock-mass are either clear and vitreous, as in the granites from Seven Lakes, or small and stained with iron, as in the rocks collected in Caylor Gulch. They are somewhat poor in fluid inclusions but show a great number of fine "quartz-needles." The iron-staining occurs as a filling in the cracks, rather than as a minutely disseminated pigment or fine evenly distributed hematite flakes.

Like the granites of the Pikes Peak type, those of the Cripple Creek type do not have very much micropegmatite developed in the fresh specimens, and when it is developed the quartz does not show the arborescent and radiate growths so abundant in the weathered and metamorphosed rocks, but is present in small rounded disks or ovals similar to those described by Romberg.[1]

The plagioclase occurs in small anhedral grains which are older than the quartz and the microcline. They are generally clouded with alteration products which may be either irregularly distributed through the individual; arranged parallel to the twinning lamellae; or concentrated in the center with a surrounding clear zone in similar optical orientation. The twinning lamellae, according to the albite law, are very fine and usually extinguish almost simultaneously parallel to their composition face.

The other constituents, zircon, apatite, and magnetite, show no unusual features and are very sparingly developed.

Distribution.—The granites of the Cripple Creek type are most characteristically developed in the area lying to the west of a line drawn from Lake George to the town of Cripple Creek and thence in a somewhat sinuous line to the waters of Oil Creek. Between this line and the volcanic deposits on the west is a broad stretch of relatively level country considerably dissected on its eastern side by Oil Creek and its tributaries.

The contacts against the Pikes Peak type are generally obscured by the presence of narrow bands of highly metamorphosed schists which were included in the older type and cut by

[1] N. J. B. B-B. VIII, 1892.

the granites of the Cripple Creek type in a manner well shown near the mouth of Arequa Gulch a few miles below the town of Cripple Creek. On the west the contacts with the gneissic granite are generally obscure, though the finer grained may be seen cutting the coarser and more schistose rock in Caylor Gulch at an elevation of 8600 feet.

The manner of weathering and the resulting physiographic forms are intermediate between those of the Pikes Peak and Summit types. The hills are neither so smooth, so bold, nor so massively jointed as those composed of Pikes Peak granite; while the disintegrated fragments are not as compact and angular as those of the Summit type. The mineralogical changes are those common to granitic minerals.

FINE GRAINED TYPE

The rocks included under this head do not occur in well-defined masses extending over large areas but in small dikes distributed throughout the entire area studied. Nor are they so closely allied in their mineralogical and textural features as members of the preceding three groups. Their correlation is based upon their composition and texture, mode of occurrence, age, and present topographic position rather than upon their areal continuity. All of these rocks are fine grained hypidiomorphic granular aggregates of reddish color, composed of quartz, feldspar, and one or both kinds of mica, with small amounts of microscopic fluorite, magnetite, epidote, zircon, and apatite.

The color of these rocks varies from brilliant red to pinkish-white or dull yellow, but is usually bright pink. In the latter case the feldspars are stained by finely disseminated iron oxide. The size of the individual grains is very constant, and rarely exceeds one sixteenth of an inch. Among the individual constituents there are several points of difference from the same minerals in the earlier types. Quartz is more abundant and in grains as large or larger than those of microcline, while incipient granulation shown by a mottled extinction is more frequent.

Among the feldspars, microcline shows a slight increase in the size of its twinning network and the plagioclase a decrease in the size and abundance of its grains. Perthitic intergrowths are practically wanting in these rocks, whether fresh or altered, while micropegmatitic intergrowths are abundant, especially in the slides where the evidences of mechanical deformation are

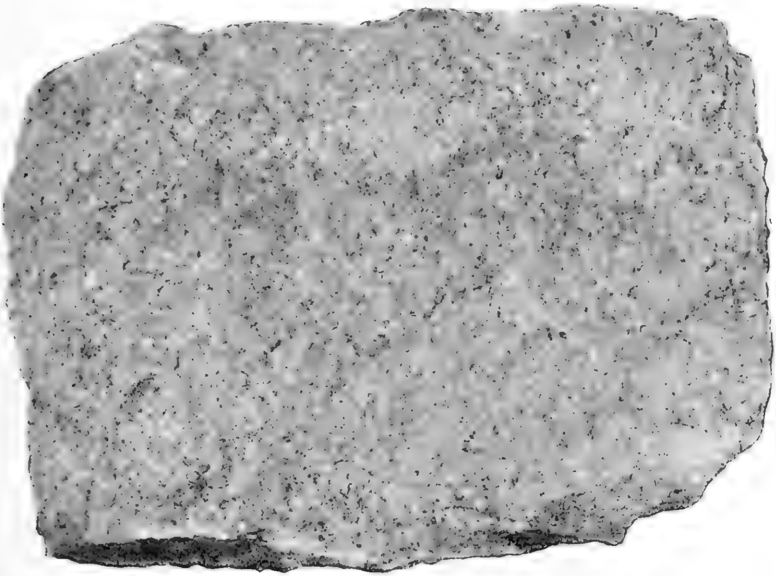

FIG. 9.—Fine grained type of granite.

most numerous. The micas show no unusual features beyond the occasional inclusion of tiny individuals of fluorite showing well-defined crystal outlines in fresh flakes of biotite.

Weathering.—The effect of atmospheric action on the fine-grained granites varies somewhat, but is ordinarily less pronounced than that on the other three types. When the rock disintegrates it usually falls into a mass of angular bowlders of small size, which are quite compact and sometimes covered with a surface glaze. This coating, which is faintly shown in Fig. 9, is much less clearly defined than is that on the Pikes Peak or

Summit types, and it does not appear to be as commonly developed. Ledge exposures of this type are comparatively rare, as the solid rock is usually covered by angular bowlders. The relatively greater resistance to weathering, due probably to the more compact texture of the rock, is clearly brought out in the topographic position of its exposures. When the fine-grained granite occurs in any considerable mass it forms the tops of minor hills and ridges. This is well shown in many places within the area of the map, the best illustration occurring on the subordinate ridges of the slopes of Pikes Peak and in the rugged area between Grouse Hill and Red Mountain, on the sides of the canyon of Cripple Creek.

TABLES SHOWING THE COMPARATIVE ABUNDANCE AND SIZE OF THE CONSTITUENTS OF THE DIFFERENT TYPES

The comparative abundance, size, and development of the various constituents in the four types of granite described in the preceding pages, are summarized in the following tables :

TABLE I. SHOWING RELATIVE ABUNDANCE OF MINERALS

	Pikes Peak	Summit	Cripple Creek	Fine grained
Quartz	abundant	abundant	abundant	predominant
Microcline	predominant	predominant	predominant	predominant
Orthoclase		fairly commonly		
Oligoclase	constant	constant	constant	constant
Perthitic intergrowths	well developed	unusual	not marked	
Micropegmatite	very rare	very abundant	rare	present
Hornblende	present			
Biotite	abundant	abundant	present	present
Muscovite				common
Fluorite	rare	very marked		present
Apatite	constant	rare	rare	present
Zircon	constant	present	constant	constant
Titanite	present			
Epidote	rare			present
Magnetite	present	rare	present	present
Hematite	present		present	present

TABLE II. SHOWING RELATIVE SIZE AND DEVELOPMENT

	Pikes Peak	Summit	Cripple Creek	Fine grained
Quartz				
Size	$3-10^{mm}$ 5^{mm} average	$2-4^{mm}$	$3-5^{mm}$	$1-3^{mm}$
Form	irregular	spheroidal	irregular	irregular
Microline	(Phenocrysts)			
Size	$6'' \times 3''$ to 15×30^{mm}, 20×30^{mm} as	25×15 to 4×7^{mm}	7×5^{mm}	
Form	well developed	well developed	well developed	
Microline	(Groundmass)			
Size	10×15^{mm}	$2. \times .05^{mm}$	1×3^{mm}	1×2^{mm}
Form	irregular	irregular	irregular	irregular
Biotite				
Size	$3-4^{mm}$	$1-2^{mm}$	1^{mm}	$0.5-1^{mm}$
Mode of aggregation..........	single and aggregate	single and aggregate	single and aggregate	single or aggregate
Texture				
Coarseness ...	coarse	Medium to fine	medium	fine
Arrangement ...	granular to porph. gran.	granitophyric	saccheroidal to orthophyric(?)	granular
Mode of occurrence	large masses	small masses and dikes	large masses	small masses and dikes

The accompanying tables show at a glance the marked similarity in the mineralogical composition, and the equally marked diversity in the textural relations presented by the different types. The diversity in the mineralogical composition of the different types is no more than that due to the presence of occasional orthoclase, hornblende, sphene, muscovite, or epidote in specimens collected over an area of more than nine hundred square miles. These types, it is true, show well developed perthitic intergrowths to be common in the fresh granites of the Pikes Peak type and wanting in the other types ; while fluorite and micropegmatite are prominent in the rocks of the Summit type and unusual in the rest of the unaltered granites. The most striking, most constant, and most characteristic differences between the types are, however, in the relative and absolute size

of the constituents, and not in the specific character of the minerals present.

The second table shows a variation in the size of the quartz constituent from grains averaging 5^{mm} in diameter in the Pikes Peak type to those of $\frac{1}{3}^{mm}$ in the fine grained granite. A similar variation is noticeable in the mica, from flakes of $0.5-1^{mm}$ in the fine grained type to those of $3-4^{mm}$ in the Pikes Peak type. The microclines also show a similar change in the same direction, whether they are phenocrysts or not; and in addition the fine-grained granites show no feldspars porphyritically developed. This uniform change in the size of the constituents can only result in the production of a similar variation in the coarseness of grain, as shown in the tables.

Table I, together with the chemical composition of the rocks, brings out the similarity or family likeness existing between the different granites; a likeness that signifies their origin from a common magma relatively rich in silica and fluorine. Table II, with the field relations, substantiates this view and explains the many local differences shown in texture, or mode of aggregation, of the different constituents. The coarse-grained Pikes Peak and Cripple Creek granites formed large masses, while the Summit and fine grained rocks occur in physical conditions sufficiently variable to account for the variations in texture which distinguish the rocks of these types.

CHEMICAL COMPOSITION

The marked uniformity in the mineralogical composition of the various granites from all portions of the area suggests a similar uniformity in the chemical composition. The abundance of quartz and perthitic microcline, with the small amounts of plagioclase, mica, and accessory minerals, indicate a relatively high percentage of silica and the alkalis, with a comparatively small amount of calcium, iron, and magnesium. The presence of fluorite, also, suggests the actually small, but relatively high, percentage of the unusual constituent fluorine. These inferences from the mineralogical composition are fully sustained by the

following complete and careful analyses made by Mr. W. F. Hillebrand of the U. S. Geological Survey.

TABLE OF CHEMICAL ANALYSES

	I (2128)	II (2531)	III (2530)	IV (2369)	V
SiO_2	77.03 1.284	75.17 1.253	73.51 1.225	73.90 1.221	74.90 1.248
TiO_2	.13 .001	.10 .001	.18 .002	.07 .000	.12 .001
Al_2O_3	12.00 .116	12.66 .122	13.28 .129	13.65 .132	12.89 .125
Fe_2O_3	.76 .004	.23 .001	.94 .006	.28 .001	.58 .003
FeO.........	.86 .012	1.40 .019	.97 .013	.42 .005	.91 .012
MnO	tr.	tr.	tr.	tr.	......
CaO.........	.80 .014	.83 .014	1.11 .020	.23 .004	.74 .013
SnO.........	......	tr. ?	......	......	......
BaO.........	tr.	.03	tr.	tr.	......
MgO........	.04 .001	.05 .01	.05 .001	.14 .003	.07 .001
K_2O	4.92 .052	5.75 .061	5.22 .055	7.99 .085	5.92 .063
Na_2O	3.21 .051	2.88 .046	3.79 .061	2.53 .040	3.10 .050
Li_2O........	tr.	st. tr.	tr.	tr.	......
H_2O*	.14	.16	.16	.15	.15
H_2O†	.30	.62	.31	.92	.55
P_2O_5	tr.	.03	tr.	.05	.02
Fl...........	.36	.31	.55	......	.31
CO_2.........	......	......	......	......	......
	100.55	100.26	100.38	99.75	......
O less F	.15	.13	.22	......	......
	100.40	100.13	100.16	99.75	100.26

* Below 110° C. † Above 110° C.

I. (2128.) A coarse grained granite of the Pikes Peak type taken from the western side of the Pikes Peak massif at a place

called Sentinel Point (12,300 feet). Feldspar is the most important constituent, with quartz very abundant in somewhat smaller grains. The mica occurs in both single individuals and in aggregates of minute flakes. A thin section of this rock is composed, almost entirely, of quartz and microcline, the latter showing a few lamellae of perthitic plagioclase.

II. (2531.) A porphyritic granite of the Summit type collected from the divide tunnelled by the Colorado Springs Waterworks (elevation about 12,000 feet). This is composed of feldspars and large grains of quartz in a fine grained, reddish to purplish groundmass.

III. (2430.) A fine grained variant of the Summit type collected on the head waters of the Middle Beaver, nearly opposite the Bear Creek road to the Colorado Springs Water-works. The prominence of the biotite against a fine grained groundmass of feldspar, and the peculiar purplish hue due to the disseminated fluorite, are the chief characteristics.

IV. (2369.) A fine grained granite of the fourth type taken from Smith's Gulch not far from Current Creek P. O. This is composed of quartz and microcline with small amounts of mica.

V. An average of the preceding.

The following conclusions based on a comparative study of the analyses seem to be warranted by the figures. When the individual analyses and their average are reduced to molecular proportions and compared with an average of twelve type analyses given by Zirkel[1] and several analyses given by Rosenbuch[2] similarly reckoned, it is seen that they all are richer in silica than the averages given in the text-books, though not richer than individual specimens from many areas. The sum of the alkalis seems to conform to that of the averages but the granites of the Pikes Peak area are relatively richer in potassium. This relation between the alkalis becomes of additional interest when the occurrence of nepheline-bearing rocks near Cripple Creek is considered.

[1] Lehrbuch der Petrographie, 2te. Aufl. II, p. 29.

[2] Elemente der Gesteinslehre, p. 186.

Among the elements represented, fluorine is of the most interest. Although small in amount the still smaller quantities of lime and phosphorus show that there is enough present to satisfy all of the latter even in the form of pure fluor-apatite, and much of the former in the form of fluorite. The possible excess of calcium is so small that the plagioclase plates must be sodium rich oligoclase and the perthitic pegs albite.

The low percentage of iron and magnesium together with the strong pleochroism of the mica explains the relative scarcity of this mineral.

The chemical analyses confirm the microscopic determinations and show that the general magma was of such a composition as might produce a rock composed essentially of a potassium feldspar, perhaps intergrown with albite, and considerable quartz, with small amounts of fluorite and iron rich mica.

RÉSUMÉ

The area included within the Pikes Peak quadrangle is a complex of granites, gneisses and schists overlain by numerous sedimentary and volcanic rocks of later age. The unaltered granites show, over an area of more than a thousand square miles, a notable uniformity in their mineralogical and chemical composition which is marked by the persistent presence of holocrystalline quartz-microcline aggregates bearing small amounts of equally constant biotite. On the other hand, these same rocks show a distinct diversity in the abundance, size, and form of their constituent minerals and the consequent differences in texture.

The variations in texture and composition are as follows:

Pikes Peak type.— Coarse granular to coarse porphyritic: rich in perthitic feldspar, poor in micropegmatitic intergrowths, and fluorite with occasional hornblende and titantite.

Summit type.— Granitophyric; poor in perthitic feldspars but rich in micropegmatite and fluorite.

Cripple Creek type.— Saccharoidal with rectangular feldspars; poor in perthitic feldspars, micropegmatite, and fluorite.

Fine grained type.— Fine granular; poor in perthitic feldspar, micropegmatite, and fluorite but bearing some muscovite.

Emphasis has often been laid on the variations in the chemical or mineralogical composition of masses showing uniformity in their texture. The present instance represents on a large scale the opposite changes. Here there are well-defined differences in texture in a mass of uniform chemical composition. The changes in mineralogical composition are slight, and represent little or no difference in the chemical proportions of the mass except in the case of the fluorite. The other changes are local and partake of the nature of "dark patches."

Besides these original differences in the textures there are others of secondary origin where the feldspar phenocrysts have become lenticular "eyes" and the massive granites have been changed to granite-gneisses.

EDWARD B. MATHEWS.

A NORTH AMERICAN EPICONTINENTAL SEA OF JURASSIC AGE

INTRODUCTION

The following line of investigation is the out-growth of the study of the faunal and stratigraphical conditions as they are expressed in the Jurassic formation of the Freeze-Out Hills in southern Wyoming.[1] In making these investigations the writer has been led to test, in the light of new doctrines[2] and more recent observations, certain prevalent opinions bearing on Jurassic faunal geography. In connection with these investigations there arose also questions concerning which no definite statement

[1] LOGAN: Kansas Uni. Quart., April 1900.

[2] See papers by DR. T. C. CHAMBERLIN on: "A Source of Evolution of Provincial Faunas," JOUR. GEOL., Vol. VI, p. 598; "The Ulterior Basis of Time Divisions," *ibid.*, p. 449.

of opinion has as yet appeared in our geological literature. Among the lines of investigation which suggested themselves were the following: (1) The nature and extent of the interior Jurassic sea; (2) the relation of the interior fauna to other faunas; (3) the connection or connections of the sea with the ocean; and (4) the causes for the lack of communication between the Interior province and the Californian faunal province.

Some of these questions, notably the second and fourth, have already received a somewhat exhaustive discussion at the hands of a number of geologists. In the majority of cases, however, the conclusions formed have been connected with certain fundamental assumptions concerning the validity of which there is at present profound skepticism. As these new doctrines are more or less intimately associated with new fundamental hypotheses, a test of the one is in a measure a test of the other; but a discussion of original postulates does not fall primarily within the province of this investigation. Therefore the discussion will proceed along the lines already indicated and in the order above mentioned.

Nature and extent of the sea.— In order to present the data upon which our conclusions concerning the nature and extent of the Jurassic sea are based it will be necessary to give a summary of the stratigraphical and faunal conditions of the present known Jurassic areas. In collecting this data I have consulted the writings of a long list of geologists who have labored in this particular geological field.[1] On the whole it may be said that the results obtained by these men are strikingly harmonious; so that no grave difficulty should be met in any attempted logical interpretation of the facts.

These Jurassic areas will be discussed in the order which follows: (1) The South Central Wyoming area; (2) the Southeastern Idaho area; (3) the Northern Uinta area; (4) the Southern Uinta area; (5) the Southern Utah area; (6) the Black Hills area; (7) the Montana area; (8) the Canadian area; (9) the Aleutian

[1] For references see following discussion.

area. Many of these terms have been used in a loose geographic sense since the object is to include under one name all of the minor localities belonging to one areal province. The numbers on the map[1] indicate the position of these areas.

THE SOUTH CENTRAL WYOMING AREA

The Freeze-Out Hills.[2]—The oldest rocks recognized in the Freeze-Out Hills are the Carboniferous. They occupy the center of the partly dissected anticline and are overlain by the Red Beds which are composed of sandstones and reddish arenaceous clays and marls inclosing here and there lenticular masses of gypsum or gypsiferous clays. These beds are seemingly devoid of fossils and are apparently conformable with the overlying Jurassic beds of unquestionable marine deposition. At a point on the Dyer Ranch the following stratigraphical conditions of the contact between the Red Beds and the Jura were noted in ascending order:[3]

1. Base, near top of the Red Beds, reddish clay, 2′+;
2. White, indurated sandstone, 4″;
3. Clay, light red, 5″;
4. White sandstone with a reddish tinge, 1″;
5. Light red clay, 2″;
6. White, slightly indurated sandstone, 6″;
7. Shale, reddish changing to purple, 4′;
8. White fissile arenaceous limestone, 6′;
9. Arenaceous clay of a dull red color, 10′;
10. White laminated arenaceous limestone containing fossils, 6″.

This last stratum contains a characteristic Jurassic type, *Pseudomonotis curta* Hall. This is the first or lowest known fossil bearing horizon of the Jura in this area. Any division line between the Red Beds and the Jura placed lower than this fossil bearing stratum would be an arbitrary one as there appears to be no unconformity to mark the separation. To the beds occurring above the fossiliferous horizon the term Jura-Trias is no

[1] See p. 245. [2] LOGAN: Kansas Uni. Quart., April 1900.

[3] Quoted from paper mentioned above.

longer applicable as they are unquestionably Jura. As the Red Beds represent the whole interval of time from the Carboniferous to the Jurassic so far as evidence to the contrary is concerned the term Jura-Trias alone is not applicable to them.

Continuing the section already begun we have for number

11. Arenaceous clay of a somewhat shaly nature, 6′. This layer contains near the central horizon a more highly arenaceous stratum of greenish color. It has scattered through it at different levels some rather large brown argillaceous concretions. The entire stratum seems to be unfossiliferous but it may contain *Belemnites densus* as it is often difficult to determine whether this fossil does, or does not, belong to the lower beds, since, on account of its abundance in the upper beds, it is usually scattered superficially throughout the full extent of the outcrop.

12. White sandy clay, 4′. No invertebrate fossils were found in this stratum but the remains of marine saurians belonging to the genera, *Ichthyosaurus* and *Plesiosaurus* occur in considerable abundance.

13. Purplish fossiliferous clay containing calcareous nodules, 20′. The most abundant fossil in this stratum is *Belemnites densus* which occurs distributed throughout the layer while the other fossils are confined chiefly to calcareous concretions. From these concretions the following forms were obtained: *Pinna kingi* Meek; *Cardioceras? cordiforme* M. & H.; *Belemnites densus* M. & H.; *Astericus pentacrinus* M. & H.; *Astarte packardi* White; *Pleuromya subcompressa* White; *Pseudomonotis curta* Hall; *Tancredia bulbosa* White; *Goniomya montanaensis* Meek; *Tancredia magna* Logan; *Lima lata* Logan; *Belemnites curta* Logan; *Cardinia wyomingensis* Logan and *Avicula beedei* Logan. This stratum contains also the remains of *Plesiosaurs* and *Ichthyosaurs*. It is the most abundantly fossiliferous of the entire series. It is also one of the most persistent beds, and is everywhere characterized by the great abundance of *Belemnites*.

14. Greenish colored sandstone separating into thin layers, 2′ to 4′. This stratum is very persistent, contains considerable calcareous matter, and is easily recognized on account of its

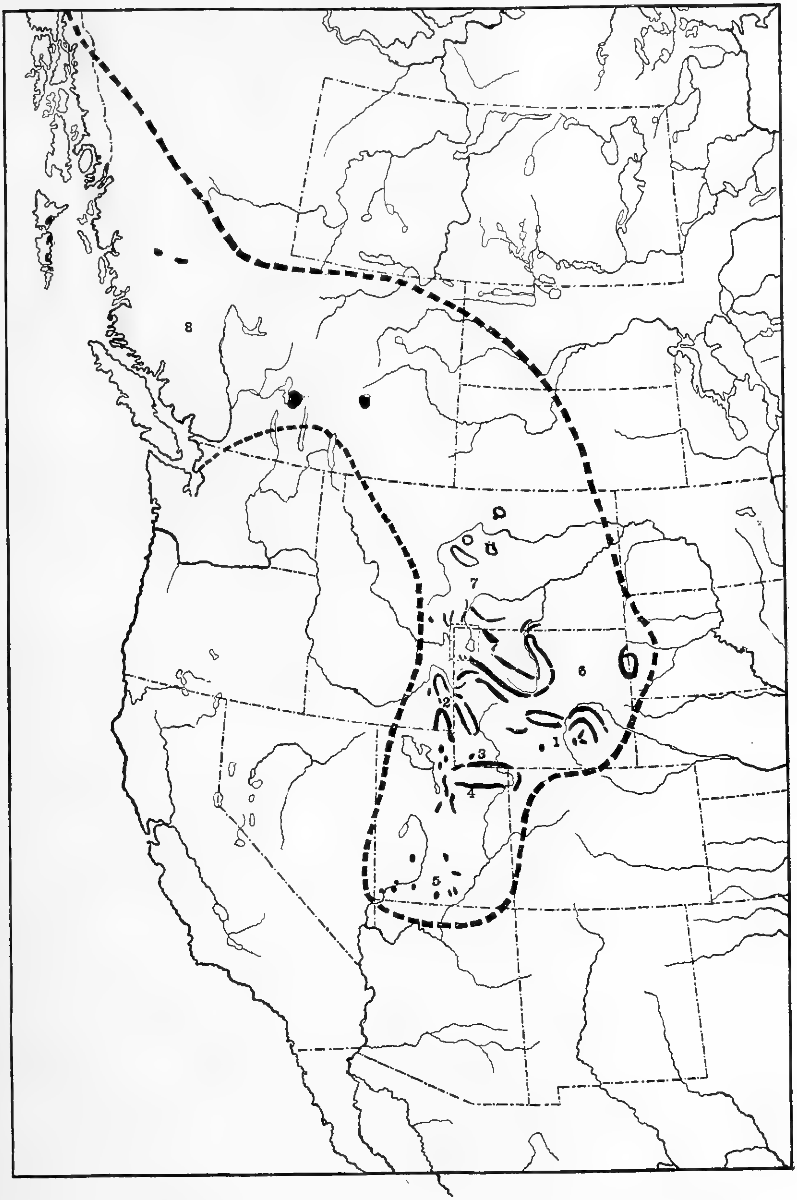

FIG. 1.—Map showing the distribution of the Jurassic formation in the interior.

uniformly greenish color. The following fossils occur in it: *Camptonectes bellistriatus* Meek; *Camptonectes extenuatus* M. & H.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Ostrea strigilecula* White and *Ostrea densa* Logan.

15. Purplish clay containing considerable arenaceous inclusions, 40′. The clay contains in the upper part a thin strata of sandy limestone in which the following fossils were found: *Pentacrinus astericus* M. & H.; *Asterias dubium* White; *Pseudomonotis curta* Hall; *Avicula macronatus* M. & H.; and *Ostrea strigilecula* White.

Como beds.—The last stratum is the uppermost one, containing marine fossils and probably closes the Jura. The succeeding layer varies so much in thickness within short distances that it may represent the slightly eroded surface upon which the Como beds were deposited.

16. Fine-grained, grayish-white sandstone, 10′ to 125′. The above stratum varies much in thickness within short distances. At one point on the Dyer Ranch it has a thickness of 10′, while a few miles southeast of that point it reaches a thickness of 125′. The sandstone composing the layer is of nearly uniform color and texture. Its induration is only moderate, and it weathers into many grotesque forms. Cross-bedding is well exhibited by it in many localities.

17. Purple to greenish colored clay, 60′. This is apparently an unfossiliferous layer except in the uppermost horizon, where species of *Dinosaurs* belonging to the genera *Brontosaurus* and *Morosaurus* occur. This is the lowest fossiliferous horizon of the Como beds and the beds included between this horizon and the layer marked 15 may represent the transition from marine to non-marine conditions.

18. Sandstone, grayish to light brown, 10′ to 20′. The above sandstone presents some very interesting stratigraphical phenomena. It has at the base a layer of conglomerate about 2½′ thick. The conglomerate is composed of small argillaceous and silicious pebbles, and is not very coherent. Something like two feet of sandstone rest upon the conglomerate; the

bedding planes of the sandstone are oblique to the beds above and below. Succeeding the sandstone above is 6″ of sandstone in very thin layers, with lignitic seams along its horizontal but wavy bedding planes. The above is overlain by 4″ of conglomerate followed by 1′ of sandstone with oblique bedding planes. Overlying this layer is a thin layer of sandstone in which the bedding planes are horizontal. The remainder of the stratum is made up of sandstones with the thicknesses and bedding planes as follows: 1′ oblique; 3″ horizontal; 2′ oblique; and finally 3″ horizontal.

The beds furnished in one place the trunk of a large fossil tree and a large number of fossil cycads. Fragments of wood were found in a number of places, but cycads in only the one. Fragments of a hollow-boned *Dinosaur* were secured from one place in the horizon.

19. Drab-colored clay, 30′ to 40′. This stratum contains the remains of *Brontosaurus* and *Morosaurus*. Otherwise it appears to be unfossiliferous.

20. Fissile, brownish sandstone, 4′ to 5′. No fossils were found in this sandstone, and a most characteristic feature about it is its uniformly brown color. It seems to be moderately persistent, as it was noticed in many places in the hills.

21. Bluish-green clay, containing very small concretions, 30′. In the bone quarries of this horizon, which furnished species of *Brontosaurus*, *Morosaurus* and *Diplodocus* were found specimens of *Lioplacodes* (*Planorbis*) *veternus* Meek, and *Valvata leei* Logan. This is the lowest horizon at which any of these non-marine invertebrates were noticed. It is very probable that they will be found in the beds below as they indicate similar conditions of deposition.

22. Brown to bluish-gray arenaceous limestone, 8″ to 1′. This stratum contains the following non-marine invertebrate forms: *Unio knighti* Logan; *Unio willistoni* Logan; *Unio baileyi* Logan; *Valvata leei* Logan; and *Lioplacodes* (*Planorbis*) *veternus* Meek. Species of the same genera have been described by Meek from a similar stratum of limestone in the Black Hills.

As these occupy much the same stratigraphical position they are very likely of the same age. The *Lioplacodes* seems to be identical with that described by Meek in the Geology of the Upper Missouri.

23. Drab-colored clay, 70′. Species of the genera *Brontosaurus*, *Diplodocus*, *Morosaurus*, *Stegosaurus* and *Allosaurus* occur in this horizon. Portions of species of all these genera were found in one quarry by the Kansas University collecting party of which the writer was a member. The clay is of that quality usually designated as joint clay. It contains, in places, iron and argillaceous concretions of small size. The iron and sometimes the bones are covered with small selenite crystals.

24. Grayish-white sandstone, 50′. This layer forms a conspicuous capping for the hills, and is the highest remnant of the anticline. It breaks up into large blocks, which lie scattered along the slopes of the underlying softer beds. Its erosion and disintegration is accomplished chiefly by sapping. No fossils were found in this stratum" (Dakota ?).

The maximum thickness of the Jura for this locality does not at the most exceed 100 feet. All of the fossils are found in a vertical range of but little more than half that distance, and yet the fauna includes all the characteristic species of the interior Jurassic province. The beds are heterogeneous and indicate constantly varying conditions of sedimentation.

The entire section is given in its minutest details so that an idea of the general character of the Como beds may be obtained. In many localities this formation has been included in the Jura, although the Jura is wholly marine while on the other hand the Como is wholly fresh water. On the whole the marine beds are more calcareous but there is usually at least one thin bed of limestone in the Como. The lithological characters of the beds do not always stand out so clearly that the evidence of fossils is not required to separate the beds.

Como Lake.[1]—The stratigraphical conditions of the formation at Lake Como are not essentially different from those of the

[1] LOGAN: loc. cit.

Freeze-Outs. The beds have the same lithological characteristics, being composed of sandstones, arenaceous clays, marls and impure limestones. They rest on the Red Beds and are overlain by about the same thickness of the Como (Atlantasaurus) beds. The latter formation is capped by an apparent continuation of the same quartzitic layer which forms the surface stratum in the Freeze-Outs. From this area the following species have been determined by the writer and others: *Asterias dubium; Pentacrinus astericus; Belemnites densus; Cardioceras? cordiforme; Pseudomonotis curta; Camptonectes bellistriatus; Ostrea strigilecula; Ostrea comoensis; Pinna kingi; Tancredia inornata; Pleuromya subcompressa; Astarte packardi;* and *Goniomya montanaensis.*

Rawlins Peak.—The Jurassic at this point exhibits about the same thickness and lithological characters as that of the Como area. The beds contain the following forms: *Camptonectes bellistriatus; Belemnites densus; Astarte packardi; Pseudomonotis curta; Ostrea strigilecula;* and *Pentacrinus astericus.*

Sweetwater.—In the Sweetwater Drainage area Endlich[1] gives 300 feet as the thickness of the jura at that place and states that it contains a Gryphea and a Belemnites.

East of the Wind River Range according to the same writer[2] the Jura has a thickness of 200 or 220 feet and consists at the base of dark calcareous shales, covered by beds of dark blue limestones. These are followed by yellow shales and marls with intercalations of thin sandstone layers. Yellow, pink and greenish marls close the section. The fossils obtained are species of *Belemnites*, *Gryphea*, *Rhynchonella*, *Lingula*, *Modiola*, *Pecten*, and others.

THE SOUTHEASTERN IDAHO AREA

In this area St. John[3] places the thickness of the Jura at 2000 feet. Since, however, only the lowermost beds are fossiliferous it is probable that the Jura should be restricted to that

[1] Ann. Rep. U. S. Geol. Surv.; Vol. XI, 1877, p. 108.

[2] *Ibid.* p. 87.

[3] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 495.

horizon. The beds consist here as elsewhere of alternating beds of sandstone, shales, and limestones.

In the Lincoln Basin the following Jurassic fossils were collected: *Ostrea strigilecula; Belemnites densus; Pentacrinus, Ostrea, Gryphea, Camptonectes*, and *Pseudomonotis.*

At Meridian Ridge Peale[1] found 150 feet of bluish and gray limestones; bluish laminated limestones and bluish argillaceous shales and slates followed by 100 feet of reddish sandstone and bluish limestone containing *Pentacrinus astericus; Ostrea strigilecula; Camptonectes bellistriatus* and other forms. This thickness of 250 feet doubtless represents a conservative average for the entire district.

On the John Day (Gray) River[2] the following fossils were collected: *Pentacrinus astericus; Belemnites densus; Camptonectes bellistriatus; Gryphea, Trigonia*, and *Pleuromya;* and from another outcrop, *Pentacrinus astericus; Ostrea strigilecula*, and *Tancredia sp.* An outcrop in the Sublette Range furnished *Pentacrinus astericus* and *Camptonectes bellistriatus.*

The Jura at Bear Lake Plateau[3] contains *Pseudomonotis curta* and other forms. The fossiliferous beds consist of 90 feet of gray limestone and 80 feet of bluish-gray limestone with bands of sandstone. This group rests on 150 feet of limestone which may also be Jura but there is no faunal evidence of its age.

On Bear River in Southwestern Wyoming Meek[4] gives the following section for the Jura: "Ferruginous sandstone, in thin layers, dipping northwest about 80° below horizon, 40 feet; bluish laminated clays with, at top (left or west side), a two-foot layer of sandstone containing fragments of shells not seen in a condition to be determined, 125 feet; Clays and sandstones, below (20 feet); gray and brown pebbly sandstone above (25 feet), 45 feet; brownish and bluish clays, with some beds of white, greenish, and brown sandstone, 115 feet." From the second layer the following fossils were obtained: *Belemnites*

[1] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 536.

[2] *Ibid.* p. 544. [3] *Ibid.* p. 585.

[4] Ann. Rept. U. S. Geol. Surv., Vol. VI, 1872, p. 451.

densus, Trigonia Quadrangularis, and *Pleuromya weberensis?* This stratum of 125 feet is all of the section that can, with certainty, be assigned to the Jura, as the other layers are unfossiliferous.

The third and fourth layers correspond in character to the Como beds in other areas in Wyoming.

THE NORTHERN UINTA AREA

Flaming Gorge.[1]— In the Flaming Gorge the total thickness of the Jurassic is placed at 700 feet. Three hundred feet near the middle of the outcrop contains: *Camptonectes bellistriatus; Gryphea calceola; Pentacrinus astericus; Rynchonella gnathophora; Trigonia americana, Trigonia conradi; Ostrea strigilecula;* and *Belemnites densus.* In the absence of fossil evidence the portion of the outcrop lying above and below this horizon cannot with certainty be assigned to the Jura. Therefore it is possible that the three hundred feet represents the whole thickness of the Jura for this area.

South of Dead Man's Springs calcareous beds which are thought to represent the middle part of the Jura for that area contain: *Camptonectes bellistriatus; Myophoria lineata; Gryphea calceola;* and *Pentacrinus astericus.*

Vermillion Cliffs.[2]—From Vermillion Cliffs in Northwestern Colorado White determined the following Jurassic species: *Belemnites densus; Cardioceras cordiforme; Pentacrinus astericus; Rhynchonella gnathophora; Rhynchonella myrina; Ostrea strigilecula; Ostrea procumbens;* and *Modiola subimbricata.*

The limits of the Jurassic sea in a southeasterly direction do not appear to have been far from this point. Northwestern Colorado has up to this time been the only part of the state to which unquestionable Jura could be assigned.

On Sheep Creek a basal limestone yielded *Camptonectes bellistriatus; Myophoria lineata; Gryphea calceola; Pentacrinus astericus; Belemnites densus;* and specimens of *Ostrea, Trigonia*, and *Volsella.*

[1] KING: Geology of the 40th parallel, Vol. I, p. 290.

[2] WHITE: Geology of Northwest Colorado, U. S. Geol. Surv., Vol. XII, 1878.

THE SOUTHERN UINTA AREA

Ashley Creek.[1]—The thickness of the Jurassic beds on Ashley Creek is estimated to be about 750 feet. Of this thickness 50 feet are blue and drab colored shales and limestones carrying *Gryphea calceola*, *Pseudomonotis* (*Eumicrotis*) *curta* and *Belemnites densus.* This stratum corresponds to the more densely fossiliferous zone of other localities. As the vertical range of the fossils is not given it is difficult to say whether all of the 750 feet should be included in the Jura.

Near Peoria on the western end of the range a basal limestone contains *Pseudomonotis curta* and is followed by a group of shales and marls. No thicknesses are given for this area.

Wasatch Range.[2]—In Weber canyon of the Wasatch Range the Jurassic is estimated to have a total thickness of 1600 feet. The lower part which consists of yellow and bluish limestones and calcareous shales has a thickness of 600 feet. It contains the following fossils: *Cucullaea haguei; Pleuromya subcompressa; Myophoria lineata; Myophoria sp.* and *Volsella scalpra.* As the upper 1000 feet of arenaceous texture is unfossiliferous it is more than probable that it is not of Jurassic age. As the vertical range of the fossils is not given we have no means of ascertaining how much of the 600 feet may, also, belong to another period.

At the mouth of Thistle Creek in Spanish Fork Canyon the following fossils were found: *Lyosoma powelli, Camptonectes stygius* and *Pinna sp.*

THE SOUTHERN UTAH AREA

According to Dutton[3] the known Jura of Southern Utah has a thickness of from 200 to 400 feet. The formation consists of a series of calcareous and gypsiferous shales. The beds are distinctly fossiliferous and thin out toward the south, entirely disappearing in northern New Mexico and Arizona. A few fossils have been collected from a number of localities in the region.

[1] KING: Geology of the 40th Parallel, Vol. I, p. 292.

[2] KING: l. c. p. 293. [3] Geology of the High Plateaus, Utah, p. 150.

From specimens collected on the Santa Clara River two miles below Gunlock White determined the following species: *Pentacrinus astericus* M. & H.; and *Trigonia sp.* Wh.; from near Kanara: *Pentacrinus astericus* M. & H.; *Camptonectes stygius* White; *Camptonectes bellistriatus* M. & H.; from the northern part of aquarius plateau; *Camptonectes platessiformis* White; *Trigonia montanaensis* Meek and *Gervillia sp.* White; from Potato Valley, Diamond Valley, and near Gunnison: *Pentacrinus astericus* M. & H.

From the geographic distribution of the Jura in this region it appears that the Jurassic sea did not extend far south of the southern boundary of Utah. It may be assumed also that its eastern as well as its western shore lines did not extend in this region much beyond the state boundaries. From this point the eastern shore line extends farther and farther east crossing the northwest corner of Colorado thence continuing toward the northeast and including the Black Hills area.

The thinning out of the beds toward the south may be due to the presence of a low land area at the south during this epoch. A high land area should give a thick shore deposit of a coarse, clastic nature. According to the above statements, however, the beds consist of calcareous and gypsiferous shales which indicate either a somewhat remote shoreline or a low bordering land area.

THE BLACK HILLS AREA[1]

The Jurassic formation forms one of the members in the rim of sedimentary rocks which encircles the crystalline area of the Black Hills. Here as in the central and southern areas the Jura rests upon the Red beds and is overlain by the Lower Cretaceous, the Como beds. Its thickness is in the neighborhood of 200 feet. It exhibits in general about the same lithological characters that are noticeable in the formation in the Southern Wyoming area. The beds consist of sandstones, arenaceous shales and marls, and thin beds of impure fissile limestone.

Whitfield[2] has determined the following species from this

[1] JENNEY: Nineteenth Ann. Rep. U. S. Geol. Surv., p. 593.

[2] Geology of the Black Hills, 1884.

area: *Asterias dubium* Whitf.; *Pentacrinus astericus* M. & H.; *Lingula brevirostris* M. & H.; *Rhynchonella myrina* M. & H.; *Ostrea strigilecula* White; *Gryphea calceola*, var. *nebrascensis* M. & H.; *Pecten newberryi* Whitf.; *Camptonectes bellistriatus* M.; *Camptonectes extenuatus* M. & H.; *Pseudomonotis curta* Hall; *Pseudomonotis orbiculata* Whitf.; *Avicula* (*Oxytoma*) *mucronata* M. & H.; *Gervillia recta* M.; *Grammatodon inornatus* M. & H.; *Mytilus whitei* Whitf.; *Volsella* (*Modiola*) *formosa* M. & H.; *Volsella pertenius* M. & H.; *Astarte fragilis* M. & H.; *Trapezium bellefourchensis* Whitf.; *Trapezium subequalis* Whitf.; *Pleuromya newtoni* Whitf.; *Tancredia inornata* M. & H.; *Tancredia corbuliformis* Whitf.; *Tancredia bulbosa* Whitf.; *Tancredia postica* Whitf; *Tancredia warrenana* M. & H.; *Dosina jurassica* Whitf.; *Psammobia? prematura* Whitf.; *Thracia? sublevis* M. & H.; *Neaera longirostra* Whitf.; *Saxicava jurassica* Whitf.; *Quenstedioceras* (*Cardioceras*) *cordiforme* M. & H.; and *Belemnites densus* M. & H.

In the Big Horn Basin region Eldridge[1] discusses the Jura as follows: "This, so far as the evidence obtained indicates, is, within the region under examination, wholly of marine origin. The thickness is between 400 and 600 feet, which is approximately maintained over the entire area of exposure. Shales constitute the mass of the formation in which from base to summit occur thin beds of sandstone and fossiliferous limestone of types characteristic of the Jura in the Rocky Mountain region. Gray is the predominating color of the shales, but throughout the formation red, purple, yellow, slate, and pink, in greater or less intensity, may be observed. At a number of localities a considerable amount of siliceous matter appears, in occurrence suggesting the action of hot waters.

"The sandstones are of slight importance. They are chiefly gray with a slight greenish tint. The lower beds, however, are red, shaly and transitional from the Trias, while near the summit are two of greater thickness, which, but for their tint and the overlying typical Jura shales, might be confounded with the Dakota.

[1] Bull. U. S. Geol. Surv. No. 119.

"The limestones are nearly all fossiliferous, and of the drab color peculiar to the Jura in the west. In thickness they vary from a few inches to 15 feet. Three or four in the lower 100 feet and one or two in the upper third of the formation are especially prominent."

The formation is said to be overlain by the Dakota sandstone. If this so-called Dakota sandstone is at the same horizon that it is in the Freeze-Out Hills, and it seems from the description very probable that it is, then the Jura so-called must include the Como beds. The description of the upper part of the formation fits the Como, while the lower part with its fossiliferous limestones is very characteristic of the Jura both north and south of this area. The Como or its stratigraphic equivalent is recognized both north and south of this region and there appears no good reason for its absence in this area.

THE MONTANA AREA

Castle Mountain.[1]—The Jurassic formation in this area is less than one half the average thickness for the interior. Its maximum thickness is only ninety feet. The formation consists of a basal sandstone overlain by a dense white limestone. The limestone layer is highly fossiliferous and contains the following well-known Jurassic forms: *Astarte packardi; Trigonia montanaensis; Pinna kingi; Pholadomya kingi; Ostrea sp.; Camptonectes extenuatus; and Gervillia montanaensis.*

The Jura of this locality rests upon upon the Carboniferous and the Red Beds are not represented. It is the belief of the writers that the beds are wanting altogether in Montana, or at least but sparingly represented.

Little Rocky Mountains.[2]—The total thickness of the Jura for this region is placed at 100 feet. The beds consist of shaly gray limestones which change to impure, marly shales and argillaceous limestones. They rest on limestones of Carboniferous age and the Red Beds are again absent.

[1] WEED and PIRSSON, Bull. 139, U. S. Geol. Surv., 1896.

[2] WEED and PIRSSON, JOUR. GEOL., Vol. IV, 1896.

The Jurassic limestones contain the following species: *Astarte meeki; Belemnites densus; Pleuromya subcompressa; Gryphea calceola*, var. *nebrascensis;* and a fragment of an undetermined Ammonite.

This is one of the most northerly areas from which Jura has been recorded for Montana. If the formation is present in the Bear Paw Mountains which lie to the northwest of this area it has not been differentiated.

Three Forks.[1]—The Jura has a thickness in this area of from 300 to 400 feet. The lower beds rest on a basal quartzite and consist of argillaceous limestones which carry characteristic Jurassic fossils. The middle and upper beds are more arenaceous than the lower beds and are non-fossiliferous. Under such conditions it is very questionable whether they should be assigned to the Jura. It is very probable that the thickness of the Jura in this area conforms more nearly to that assigned to it in other areas of Montana.

Livingston.[2]—The Jurassic formation of the Livingston area has a thickness estimated at 400 feet. It consists at the base of a massive, cross-bedded, ripple-marked sandstone. This sandstone is overlain by a layer of impure fossiliferous limestone containing *Pleuromya subcompressa* M. The limestone is followed by a bed of arenaceous limestones containing shell fragments. Since the lower layer is non-fossiliferous it may or may not represent a part of the Jura, but there is the possibility of an overestimation of thickness here as well as in the Three Forks area.

Although the thicknesses given for the Three Forks and Livingston area are not extremely large, yet they are nearly double that given for the other Montana areas. But as has been pointed out, this lack of harmony may be due to the inclusion of beds belonging to other formations. If the faunal relations are not carefully worked out in connection with the stratigraphy errors are likely to occur either in the direction of the overlying

[1] PEALE, U. S. Geol. Surv., Three Forks Folio, 1896.

[2] IDDINGS and WEED, U. S. Geol. Surv., Livingston Folio, 1894.

or the underlying beds. For the Jura in many localities, so far as physical characters are concerned, grades almost imperceptively into the Red Beds below and the Como above.

Judith Mountains.[1]—Weed and Pirsson give the following section as representing the Jura in the Judith Mountains. The base is separated from the Carboniferous by a sheet of porphyry.

		Feet.
1.	Limestone, dark gray, laminated, and shaly - - - - -	10
2.	Limestone, blue to gray in color, hard in texture, and carrying Ostreæ in 3 to 5-foot beds, separated by thinner platy beds -	12
3.	No exposure - - - - - - - - - - - - -	25
4.	Shaly, argillaceous, impure limestone, dove colored, weathering buff on joint faces and of typical Jurassic aspect - - -	5
5.	Shaly beds, seldom exposed, carrying oolitic limestone. Green or sandy limestone of drab color - - - - - - -	15
6.	Rough weathering limestone, fine grained, cross-bedded and fissile, carrying fossils - - - - - - - - - - -	5
7.	Sandy limestone like that above, but irregularly bedded and resembling sandstone; granular and saccharoidal in texture, carries shell fragments - - - - - - - - - - - -	4
8.	Irregularly platy, earthy-brown, gray limestone carrying shell remains of *Gryphea* and *Ostrea*, weathering dark brown, rarely granular - - - - - - - - - - -	6
9.	Marly shales and limestone, dove colored, carrying fossils noted in following pages, seldom exposed, *Gryphea* most abundant here -	30
10.	No exposure, but débris of sandstone - - - - - -	60
11.	Ellis sandstone, variable, buff, platy sand rock; pink blotched at base with occasional shells; cross-bedded purple-brown outcrop. It is at the top a limestone full of black and white quartz sand grains and forms a dark brown ridge - - - - - - - - -	12

This section gives the total thickness of the Jura for this region at 184 feet, which is nearly double that of the Little Rocky and Castle Mountain areas.

The fossils collected from the horizon mentioned above are: *Ostrea strigilecula* White; *Gryphea calceola* var. *nebrascensis* M. & H.; *Modiola subimbricata* M.; *Cucullaea haguei* M.; *Pleuromya subcompressa* M.

[1] WEED and PIRSSON, Eighteenth Ann. Rept., U. S. Geol. Surv., III, p. 445.

Yellowstone Park.[1]—The thickness of the formation for this area is placed at 200 feet. It consists of sandstones, marls, limestones, and clays, and contains, according to Stanton,[2] the following species: *Pentacrinus astericus* M. & H.; *Rhynchonella myrina* Hall & Whitf.; *Rynchonella gnathophora* M.; *Ostrea strigilecula* White; *Ostrea engelmani* M.; *Gryphea planoconvexa* Whitf.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Lima cinnabarensis* Stan.; *Camptonectes bellistriatus* M.; *Camptonectes bellistriatus* var. *distans* Stanton; *Camptonectes pertenuistriatus* Hall & Whitf.; *Camptonectes platessiformis* White; *Avicula* (*Oxytoma*) *Wyomingensis* Stan.; *Pseudomonotis Curta* (Hall)?; *Gervillia montanaensis* M.; *Gervillia* sp. Stan.; *Modiola subimbricata* Meek; *Pinna kingi* M.; *Cucullaea haguei* M.; *Trigonia americana* M.; *Trigonia elegantissima* M.; *Trigonia montanaensis* M.; *Astarte meeki* Stan.; *Astarte* sp. Stanton; *Tancredia? knowltoni* Stan.; *Protocardia shumardi* M. & H.; *Cyprina? Cinnabarensis* Stanton; *Cyprina? iddingsi* Stanton; *Cypricardia? haguei* Stanton; *Pholadomya kingi* M.; *Pholadomya inaequiplicata* Stan.; *Homomya gallatinensis* Stan.; *Pleuromya subcompressa* M.; *Thracia weedi* Stanton; *Thracia? montanaensis* (Meek)?; *Anatina* (*Cercomya*) *punctata* Stan.; *Anatina* (*Cercomya*) sp. Stan.; *Neritina wyomingensis* Stan.; *Lyosoma powelli* White; *Turitella* sp. Stan.; *Natica* sp. Stan.; *Oppelia?* sp. Stan.; *Perispinctes* sp. Stan.; and *Belemnites densus* Meek and Hayden.

THE CANADIAN AREA

In the Queen Charlotte Islands Whiteaves[3] noted the occurrence of the following species, which are common to the Jura of the Interior: *Pleuromya subcompressa* Mk.; *Astarte packardi* White; *Avicula* (*Oxytoma*) *mucronata* Mk.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Lyosoma powelli* White; *Belemnites densus* M. & H.; *Belemnites skidgatensis* Whiteav.; *Grammatodon inornatus* Whiteav.; *Modiola subimbricata* Mk.; and *Camptonectes extenuatus* Mk.

Although Whiteaves recognized the interior affinity of these forms, he was inclined to put both groups into the Cretaceous

[1] U. S. Geol. Surv., Yellowstone Park Folio, 1896.

[2] U. S. Geol. Surv., Yellowstone Park Monograph, XXXII, p. 601, 1899.

[3] Geol. Surv., Canada, Mesozoic Fossils, Vol. I.

rather than the Jura. But the Jurassic age of these beds is now sufficiently well established not to require further discussion.

Not only is this fauna represented in the islands just mentioned, but it occurs also on the continent at some considerable distance inland. From fossils collected by G. M. Dawson on the Iltasyouco River in British Columbia about Parallel 53° and Longitude 126° West, Whiteaves[1] recognized the following species: *Pleuromya subcompressa* Mk.; *Pleuromya lævigata* Whiteav.; *Astarte packardi* White; *Trigonia dawsoni* Whiteav.; *Modiola formosa* M. & H.; *Gervillea montanaensis* Mk.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Grammatodon inornatus* Whiteav.; *Oleostephanus loganianus* Whiteav.

These fossils were found in the felsites and porphyrites of the metamorphic rocks lying east of the Coast Range. They contain species common to both the Queen Charlotte and the Interior faunas.

From fossils collected by G. M. Dawson at Nicola Lake in British Columbia Hyatt[2] determined the Jurassic age of certain beds in that region lying above the Triassic. The fossils collected are: *Rhynchonella gnathophoria?; Pecten acutiplicatus* Gabb; *Entolium* sp. Hyatt; *Lima parva* Hyatt.

Just north of Parallel 51°, near the east end of Devil's Lake, which is situated on the eastern border of the Front Range of the Rockies, McConnell[3] found an outlier of Jurassic which contained the following fossils: *Avicula* (*Oxytoma*) *mucronata; Trigonia intermedia; Trigonarca tumida; Terebratula*, *Ostrea*, *Camptonectes*, *Lima*, *Cyprina*, *Ammonites*, and *Belemnites*. This locality serves as a connecting link between the Montana area and the localities to the west, as it is situated midway between the two. The above-named group of fossils contains one species and a number of genera common to the Interior and the Pacific Coast deposits.

[1] Loc. cit.

[2] Rept. of Geol. Surv., Canada, 1894, p. 51.

[3] Rept. of Geol. Surv. Canada, 1896, p. 17d.

THE ALEUTIAN AREA

Grewingk[1] was the first to announce the occurrence of beds of Jurassic age in Alaska. These beds were discovered at different places along the Alaskan Peninsula and the Aleutian Islands. From the distribution of these beds as mapped by Grewingk the Alaskan Peninsula and the Aleutian Islands must have been under water during Jurassic times.

In 1872 Eichwald[2] described an assemblage of fossils collected from these same beds and correlated them with the Northern Russia beds of the same age, but put both formations in the Lower Cretaceous. Some fossils were collected from the same region by Dall in 1883. These forms were described by White,[3] who after making a study of them and comparing them with Eichwald's descriptions, decided that the latter was wrong in his assignment of the beds to the Cretaceous. He found them to be closely allied to the Jurassic of Northern Russia. One species, *Aucella concentrica* Fisher, he considers either identical or only a variety of the Eurasian Jurassic form of that name.

Hyatt,[4] in speaking of these deposits, says: "The fauna of the Black Hills, acknowledged to be Jurassic by everyone but Whiteaves, is in part apparently synchronous with that of the Aleutian Islands and Alaska, as described by Eichwald and Grewingk."

The position of these beds and the relation of the fauna with the northern Eurasian fauna points clearly to an Arctic-Pacific connection by way of the Bering waters during this epoch. Moreover we now have an almost continuous faunal record extending from Alaska to southern Utah.

Conclusions.—An examination of the above sections will show that the thickness of the Jura in the interior is not very great. An average of ten localities gives a thickness of but little over

[1] Russian Kaiserl. Mineral Gesell., 1848–9.

[2] Geognostisch-Paleontologische Bemerkungen über die Halbinsel Mangischlak und die Aleutschen Insel.

[3] Bull. U. S. Geol. Surv. No. 4, 1884.

[4] Bull. Geol. Soc. Am., Vol. V, 1894, p. 409.

two hundred feet. In fourteen localities the thickness is under four hundred feet. These localities are scattered throughout the length and breadth of the interior province. In all the areas for which greater thicknesses have been recorded there are none in which the entire thickness could, without question, be assigned to the Jura.

The lithological character of the beds is much the same for all areas. The formation consists everywhere of essentially the same group of arenaceous clays, shaly marls, impure limestones and sandstones. The order of succession of the beds implies ever changing conditions of sedimentation. Thin beds of sandstone are overlain by thin beds of fossilferous clays, marls, or limestones; and these in turn are followed by another similar group.

The absence of any considerable thickness of limestone over a large area indicates that for no great period of time were the waters of the sea entirely free from clastic sediments. The presence of cross-bedded sandstone and ripple-marked layers at different horizons, the almost universal presence of *Ostrea* and other shallow water forms, together with the stratigraphic and lithologic characters just mentioned prove that the waters of the sea were not of great depth; that the sea was not of the abysmal type. It was not a sea comparable in depth to the Mediterranean but was a shallow epicontinental sea. From the geographic distribution of the known Jurassic the outlines of this sea were as indicated on the map[1] accompanying this paper.

From the character and extent of the sea it may be assumed that no extensive epeirogenic movement was necessary for its inauguration, providing the antecedent topographic conditions were favorable. In the northern part of the area there is evidence that a considerable period of erosion preceded the Jura, as the Red Beds are absent and the Jura rests on the Carboniferous. This period of erosion may have been sufficient to reduce the land area to approximate base level in which case a very slight warping would have been sufficient to let the waters of this

[1] See p. 245.

shallow sea in upon the continent. A very slight increase in the capacity of the ocean basin would suffice to draw the water off the continent at the close of the period. The increase in the capacity of the ocean may have been accomplished by a slight settling of the oceanic segment. The withdrawal of the waters of the epicontinental sea was doubtless the initial step in the movement which ended in the elevation of the Sierra Nevada Mountains; for the withdrawal took place at the close of the Oxfordian stage or during the Corallian and according to Diller[1] the orogenic movement which produced the Sierra Nevada and Klamath Mountains took place at the close of the Corallian. If these interpretations be logical ones we may assume that it required little or no bodily movement of the continent to produce either the inauguration of the Jurassic sea or its withdrawal from the continent. It may be asserted further that there is nothing connected with its history which is inimical to the doctrine that the continent had in general its present outline during Jurassic times and that the waters of the submerged portions were of an epicontinental nature.

The writer's study of the faunal conditions in the field has led him to the opinion that only one fauna is to be recognized in the Jurassic deposits of the interior province. A comparison of the fossils collected from the different areas just discussed serves to strengthen the opinion. Everywhere the formation is characterized by about the same group of fossils, of which the more characteristic ones are: *Pentacrinus astericus*, *Belemnites densus*, *Camptonectes bellistriatus*, *Pseudomonotis curta* and *Cardioceras cordiforme*. These forms all existed contemporaneously.

Stanton[2] discusses the view expressed by Hyatt[3] that more than one Jurassic fauna may be represented in the Interior and arrived at the following conclusion: "the stratigraphic relations and the geographic distribution of the marine Jurassic of the Rocky Mountain region are in favor of the idea that all of these deposits were made contemporaneously in a single sea."

[1] Bull. Geol. Soc. Am. Vol. IV, p. 228.

[2] U. S. Geol. Surv. Yellowstone Park Monograph XXXII, 1899, pp. 602–604.

[3] Bull. Geol. Soc. Am. Vol. III, 1892, pp. 409–410.

This fauna according to Hyatt belongs to the Oxfordian stage of the Upper Jura or Malm. In the Taylorville series of California he recognized the Callovian, the Oxfordian and the Corallian stages of the Upper Jura. But as has been stated above none but the middle stage has been recognized in the Interior.

Relation of the interior fauna to the northern eurasian fauna.—The discovery of beds of Jurassic age in the interior was first announced by Meek[1] in 1858. In correlating these beds with the Jura of the Old World he says: "The organic remains found in these series present, both individually and as a group, very close affinities to those in the Jurassic epoch in the Old World; so close indeed, that in some instances, after the most careful comparisons with figures and descriptions, we are left in doubt whether they should be regarded as distinct species, or as varieties of well-known European Jurassic forms. Among those so closely allied to foreign Jurassic species may be mentioned an Ammonite we have described under the name of *Ammonites cordiformis* which we now regard as probably identical with *Ammonites cordatus* of Sowerby; a *Gryphea* we have been only able to distinguish as a variety from *G. calceola* Quenstedt; a *Pecten*, scarcely distinguishable from *Pecten lens* Sowerby; a *Modiola*, very closely allied to *M. cancellata*, of Goldfuss; a *Belemnite*, agreeing very well with *B. excentricus*."

Since the publication of the above statements by Meek the paleontology of the European Jura has been more completely worked out and some of the faunas, particularly that of northern Russia, are found to have still closer affinities to the American interior fauna. The Jurassic faunas of America have also received many additions at the hands of the American paleontologists Gabb, Hyatt, Meek, Smith, Stanton, White, Whiteaves, and Whitfield. All of these studies have tended to strengthen the opinion just expressed.

The following comparison of forms which are so closely allied as to deserve, in many cases, to be called varieties of the same species will serve to show the close affinity of the interior

[1] Geological Report of the Exploration of the Yellowstone and Missouri Rivers.

American fauna to the fauna of northern Eurasia: *Belemnites panderanus* d'Orb. and *Belemnites densus* Mk.; *Astarte duboisianus* d'Orb. and *Astarte pakardi* White; *Avicula volgensis* d'O. and *Avicula mucronata* Mk.; *Pentacrinus scalaris* Goldf. and *Pentacrinus astericus* M. & H.; *Goniomya dubois* d'Orb. and *Goniomya montanaensis* Mk.; *Gryphea calceola*, Quen. and *Gryphea caceola* var. *nebrascensis* Mk.; *Cardioceras cordatus* Sow. and *Cardioceras cordiforme* Mk. The faunas taken as a whole exhibit the close relationship in a much more forcible manner than the comparison of a few species.

This northern Eurasian, or *Cardioceras* fauna is thought to have had its origin on the northern shores of the Eurasian continent, and to have migrated from there to American waters. This assumption is based on the sudden appearance of the fauna in America and its close affinities with older Eurasian faunas. The present geographic distribution of the fauna indicates a northern connection.

A later Jurassic fauna, the *Aucella* fauna, probably had its origin in the north and migrated to Pacific waters. This fauna, however, did not reach the interior province of America as the waters of the epicontinental sea had been withdrawn before its appearance. This later migration extended along the Pacific coast as far south as Mexico.

Both of the faunas just mentioned belong to the Upper Jura, but the Lias and Middle Jura are also represented in the Californian province. The Upper Jura, however, represents the maximum encroachment of the ocean on the American continent as well as on the Eurasian continent. It also marks the maximum expansion of marine life, induced doubtless by increased feeding grounds.

Connection of the sea with the ocean.—The question as to where the interior sea had its connection, or connections, with the ocean is important in estimating the extent of the submergence, That the sea had a Pacific Ocean connection there seems no longer room for doubt. The occurrence in the Queen Charlotte fauna of so many species common to the interior places the

question beyond controversy. That there was communication between the Arctic and the Pacific is supported by the presence of Arctic species in the Pacific fauna. From the distribution of the Jurassic sediments as given in the preceding pages it may be asserted with a measurable degree of confidence that the connection between these two bodies of water was during Jurassic times as it is today by way of the Bering waters. As the presence of Jurassic deposits on the Alaskan Peninsula and the Aleutian Islands testify to the submergence of those areas, it may be assumed that communication between the two oceans was somewhat freer than at present.

The question which is now brought to mind is whether the interior sea had any other connection with the ocean. The character of the fauna excludes any hypothesis favoring a southern connection either with the Gulf of Mexico or the Pacific. If there had been such a connection a southern facies would be expressed in its fauna. Such evidence is entirely absent. The evidence against any other Arctic connection is largely negative, but as such is measurably strong. The investigations of American and Canadian geologists have failed to bring to light any Jurassic deposits in the North aside from those already described, although approximately the whole area where we should expect to find them has been gone over.

McConnell,[1] who made geological investigations in Athabasca and along the Finlay and Porcupine Rivers, found Cretaceous beds resting on Devonian and Carboniferous strata. The interval of time which elapsed between the Carboniferous and the Lower Cretaceous is not represented in this region.

Spurr[2] found the same conditions to obtain for the Upper Yukon region of Alaska and the neighboring British territory. The Lower Cretaceous rests on Devonian or Carboniferous rocks. As before stated this evidence is merely negative. Jurassic rocks may have been deposited and afterwards cut away. But,

[1] Geol. Survey of Canada, Vols. V and VII.

[2] Geol. of the Yukon Gold District, U. S. Geol. Surv., Seventeenth Ann. Rept., 1897.

in that case, we should expect to find remnants of the former beds unless it be assumed that a long interval of time preceded the deposition of the Lower Cretaceous. Paleontologic and stratigraphic evidence is not in harmony with this assumption. The Lower Cretaceous beds of California which are but slightly unconformable with the Upper Jurassic, having a closely related fauna, are correlated with the Lower Cretaceous of the region under discussion.[1]

In many places in the interior region the Lower Cretaceous rests conformably on the Jurassic. This fact has been fully brought out in the preceding pages. It cannot be affirmed that the interior sea first had its connection with the Arctic and then gradually spread its waters farther and farther west until it united with the Pacific. For if this were true we should find in the interior first a fauna composed wholly of northern species, followed later by a fauna containing both Arctic and Pacific types. But no such conditions find expression in the faunal relations of the interior. Only one fauna exists in the interior.

There exists at present no evidence which will support the view held by Neumayr,[2] that the whole of Alaska and all of that portion of British America lying north of the interior Jurassic area of the United States was submerged during this epoch. All that can be asserted positively is that the Aleutian Islands and Alaskan Peninsula, in part at least, a narrow margin along the Alaskan coast and a wider area in California and Mexico was under water, while an arm of the Pacific extended in upon the continent from the region of the Queen Charlotte Islands.[3]

Lack of communication between the provinces.—The Jura of California and Nevada contains a fauna which is very different from that of the interior, although the faunas are contemporaneous. To explain the difference between the two faunas Neumayr assumed that that they belonged to two distinct climatic provinces. He assumed that the interior fauna was a Boreal fauna

[1] Spurr, l. c., p. 183.

[2] See map p. 267, copied from Erdgeschichte, p. 336.

[3] See map p. 245.

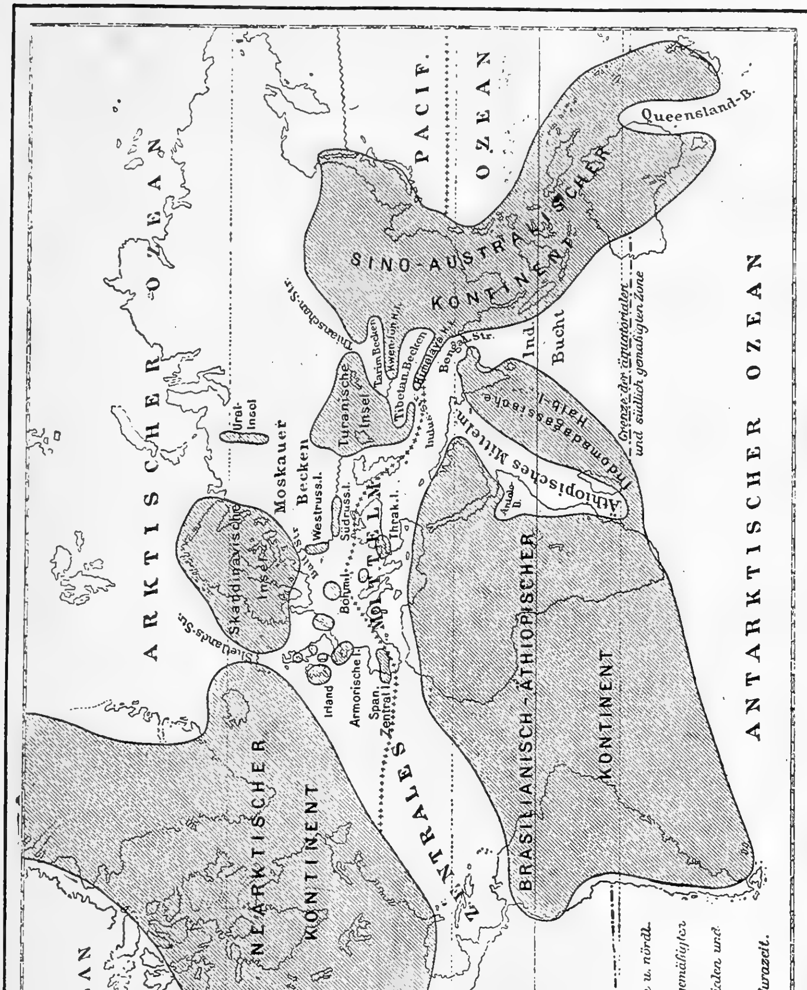
ARKTISCHER OZEAN
ARKTISCHER OZEAN
PACIF. OZEAN
NEARKTISCHER KONTINENT
SINO-AUSTRALISCHER KONTINENT
BRASILIANISCH-ÄTHIOPISCHER KONTINENT
ZENTRALES MITTELMEER
PACIFISCHER OZEAN
ANTARKTISCHER OZEAN
Queensland-B.
Uinta B.
Skandinavische Insel
Shetlands-Str.
Ural-Insel
Moskauer Becken
Westruss. I.
Südruss. I.
Thrak. I.
Böhm. I.
Irland
Armorische I.
Span. Zentral I.
Turanische Insel
Tarim Becken
Tibetan. Becken
Himalaya
Indus
Bengal. Str.
Ind. Bucht
Indomadagassische Halb-I.
Äthiopisches Mittelm.
Angola B.
Grenze der borealen u. nördlich gemäßigten Zone
Grenze d. nördlich gemäßigten und äquatorialen Zone
Grenze der äquatorialen und südlich gemäßigten Zone
Grenze zwischen der borealen u. nördl. gemäßigten Zone.
Grenze zwischen der nördlich gemäßigten und äquatorialen Zone.
Grenze zwischen der äquatorialen und südlich gemäßigten Zone.
Ausdehnung d. Festlandes zur Jurazeit.

FIG. 2.

which lived in an arm of the Arctic Ocean, and that the Californian fauna belonged to another climatic province, the north temperate.

In a recent discussion of the subject Ortman[1] has shown very conclusively that the faunal differences of Jurassic times, so far as the Eurasian continent is concerned, were not due to climatic zones. The distribution of the interior or Cardioceras fauna favors this view for the North American continent, The Cardioceras fauna is found distributed through a range of latitude extending from 37° to 80° north. Its southernmost extension is not as placed by Neumayr in the neighborhood of 46°, but is at least as far south as 37°, and is found in approximately the same latitude as the Californian province. Moreover, the later (for the American region) Jurassic fauna, the Aucella, has been reported from Mexico.[2] The Aucella fauna also had its origin in northern Eurasian waters. Its geographic range was from 80° north to 25° north. This means an extension of Neumayr's Boreal province to within 25° degrees of the equator! The great geographical range of this fauna indicates that there was little or no climatic restriction to its migration. In so far as the evidence can be deduced from the geographic distribution of the American Jurassic faunas the climate of the period may be said to have been more uniform than it is today.

The above facts are perhaps sufficient to show the weakness of the climatic-zone hypothesis. It now remains to suggest an alternative line of investigation. In seeking for the causes for the want of communication between the provinces it may be possible to draw some analogy from the faunal and topographic conditions as they exist today on the Pacific coast. There are at present on the Pacific coast, according to Fischer,[3] two faunal provinces, the Aleutian, corresponding in position to the Queen Charlotte of Jurassic times, and the Californian, corresponding to the Jurassic province of the same name. The line

[1] Am. Jour. Sci. Vol. I, 1896, p. 257.

[2] Nitikin, Neus Jahrb. Min. Geol. Pal., 1890, II, p. 273.

[3] Manuel Conchologie.

separating these two provinces is placed in the vicinity of Vancouver Island. The faunal interrelations of these two provinces are as follows: Of seventy-eight genera occurring in the two provinces nine are common to both ; of one hundred and four species six are common to both ; and of ten circumpolar species which have reached Vancouver Island and Puget Sound only four occur in California, and but one in Lower California.' From these conditions it will be seen that communication between the two provinces is almost, if not quite, as thoroughly prohibited now as it was during Jurassic times. The question which now arises is what restricts communication between the two provinces at present? It cannot be said to be due to climate alone, for why in that case should the circumpolar species be found so far south? And why should they all be found in Puget Sound and not be found farther south? This seems to be an exception to the general rule that the climatic provinces of the present time are connected by transition zones. For the line of demarcation is moderately sharp.

Aside from the matter of climate there are two physiographic conditions which may be operative. The first of these lies in the extreme narrowness of the sumerged shelf lying to the north and west of Puget Sound. This shelf teeming with organisms already well established offers small inducement to migratory forms. And only the more hardy forms would be likely to survive the struggle for existence under such circumstances as are here postulated. Thus the change of species from one province to the other is necessarily slow.

There are good reasons for believing that throughout the Mesozoic era these topographic conditions of the Puget Sound region were much as they are at present. During the Horsetown epoch the Pacific shoreline, although it lay a considerable distance east of the present shoreline in California and Oregon, very closely approximated it in the Puget Sound area. The Chico also had a very restricted epicontinental area at that point as the Chico shoreline extended only to the eastern coast of Puget Sound. In California and Oregon, however, its eastward

extension was far beyond that of the Horsetown.[1] The Jurassic beds do not occur in the Puget Sound region, and as they underlie the Horsetown elswhere, it is evident that the Jurassic shoreline at this point must have been at least as far west as the present shoreline.

A second cause for the lack of communication between the two provinces may lie in the position of the ocean currents. The Californian currents coming from the west along a line lying between the Queen Charlotte Islands and the island of Vancouver turns south at some notable distance from the coast, and after passing Vancouver bears toward the coast and flows on along the Californian province. The North Pacific current which flows east closely parallel to the Californian bears northward before reaching the Queen Charlotte Islands. Neither of these currents, since they do not cross the line separating the two provinces, is effective in establishing communication by carrying embryonic or larval forms which might under different circumstances be brought within their reach. This same distribution of ocean currents probably held during Jurassic times, as in general, the large land masses in this region, at least, had their present distribution.

The attractive feeding ground furnished by the epicontinental sea doubtless exerted its influence to prevent southern migration. When later the waters were drawn off the continent the accumulation of the great numbers of organisms on the coast may have been sufficient to force the migration southward. Or perhaps the interval of time was sufficiently long for some of these northern species to have forced their way into the Californian province during later Jurassic time. In either case we would have in the Upper Jurassic faunas of California a northern element, and this seems a well-established fact. Nevertheless, since this Upper Jurassic fauna has been reported from Mexico it is evident that communication was freer between the two provinces after the withdrawal of the waters of the epicontinental sea. And it is very likely that the movement which caused

[1] See map p. 271.

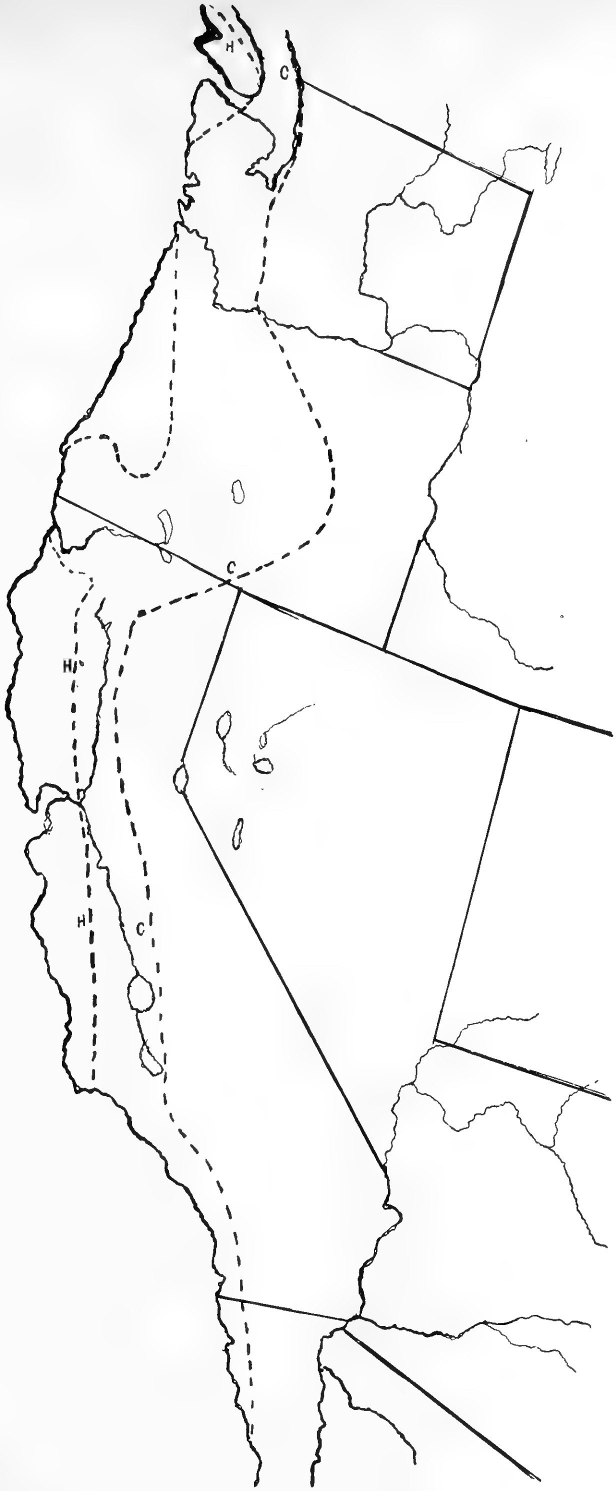

FIG. 3.—Map showing the approximate position of the Chico (C) and Horsetown (H) Shore lines (after Diller and Stanton).

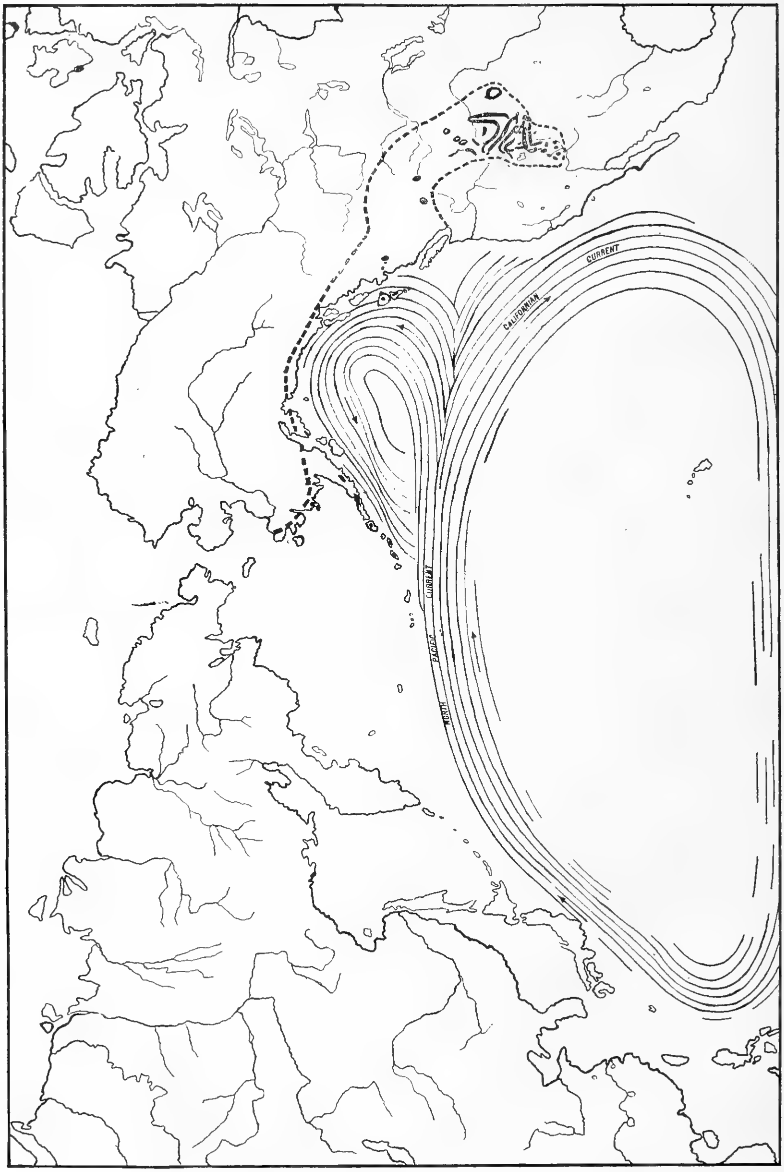

FIG. 4.—Map showing the position of the North Pacific Currents and the approximate outline of the Jurassic Sea.

the withdrawal also slightly depressed the barrier between the provinces.

Final conclusions.—It now remains to state briefly, in review, the conclusions to which the lines of investigation have led. They are as follows: 1. The Jurassic formation of the interior province of North America was not deposited in a body of water of even moderate oceanic depth, but in a shallow epicontinental sea.

2. This sea had but one connection with the ocean and that connection was with the North Pacific in the Queen Charlotte Island region; in general the outlines of the sea were as indicated on the map accompanying this article.

3. There was a connection, during this epoch, between the Arctic and Pacific by way of the Bering waters, and by this means circumpolar and Pacific faunal communication was established.

4. The Jurassic deposits of the interior contain but one fauna and if more than one period of time is represented it is not indicated by a change in the fauna.

5. The fauna of the interior is closely allied to the Cardioceras fauna of northern Eurasia.

6. Physiographic rather than climatic condition restricted communication between the Californian and interior provinces.

7. Nothing connected with the history of this Jurassic sea or its faunal relations is inimical to the view that during this epoch the North American continent had, in general, its present outline.

8. The geographic distribution of land and water, as postulated by Neumayr for this period, is not supported by the facts, in so far as the North American Jura is concerned.

W. N. LOGAN.

EDITORIAL

Geologists heartily participate in the satisfaction which astronomers justly feel over the great mass of accurate data which favorable conditions and their own zeal and skill enabled them to gather from the recent solar eclipse. Geologists offer their cordial felicitations not only as fellow scientists rejoicing in the common advancement of science for its own sake, and for its influence on the world, but because they are themselves concerned in the solution of the solar problems. Especially are they interested in those questions of the sun's constitution and internal activities which bear upon his sources of heat, present, past, and future; for these vitally touch the limitations of geologic history. It is impossible, therefore, for historical geologists to be indifferent to the results of any investigation that promises to throw light upon the thermal endurance of the sun.

The central subject of interest in the recent observations, the constitution of the corona, may seem quite remote from any geologic relationship, but, as in so many other cases in the history of science, light upon dark problems may come from an unexpected source. It is not beyond the limits of speculation to conceive that the corona may prove to be the very phenomenon that will point the way to a revised estimate of the thermal possibilities of the sun and thus to a revised measure of its past duration and of the age of the earth as one of its dependencies. Some hint of the possibilities may be found in the logical sequences of one of the alternative working hypotheses relative to the coronal nature. If the conception that it is formed of extremely attenuated matter driven away at great velocities, after the analogy of the tails of comets, should be substantiated, it will necessarily be followed by the problem of the origin of such attenuated matter. In the case of comets such supposed matter may be assumed to be simply an accessory constituent brought in from distant space and developed by approach to the sun — and soon exhausted in the case of captured comets — but such a

hypothesis does not seem well fitted to the sun itself in this late stage of its history. The alternative conjecture that the attenuated form of matter is developed in the sun by the extraordinary agencies operative there must obviously be entertained until disproved, and the recent investigations of J. J. Thompson and others with reference to the extremely attenuated ionization of terrestrial gases under certain conditions render such a hypothesis less highly improbable than it would have seemed under the dominance of the inherited doctrine of the indivisibility of the atom.

A speculation which involves the notion of the divisibility of the atom involves also that of the divisibility of the internal energies of the atom and their possible transformation into radiant energy, and hence a possible source of heat of unknown and, at present, quite incalculable amount.

So too, a speculation which assumes that the corona is radiated matter involves also the conception of loss of sun's substance if the velocity of radiation be as high as that attributed to the conjectural matter of comets' tails; and if this loss of matter in the course of great secular periods becomes appreciable, it may require a reconsideration of the data upon which estimates of the sun's heat are based and also of a revised consideration of the former distances of the planets.

Now such an attenuated chain of hypotheses, each dependent on an antecedent hypothesis of uncertain verity, may be altogether too unsubstantial to have any appreciable value of the positive sort, other than as the antecedent of investigation, but it may have the negative virtue of helping to keep open the question of the sum total of the sources of the sun's heat and its possible duration in the past and the future. And so possibly may also the logical sequences of the alternative coronal hypotheses. The Helmholtzian theory assigns a source of heat of such competency that it cannot be proved not to be the sole essential cause by any measurements of the sun that can be made now, or probably in the near future, and hence it satisfies the immediate demands of astronomical science, however inadequate it may be to meet the natural interpretations of geological and biological data;

but it may be conjectured that when the history of the stellar system shall become as serious and substantial a subject of study as the history of the earth now is, astronomers will find at least as great need for long lapses of time and for the secular endurance of thermal states as do the geologists and biologists.

Meanwhile all solar inquiries are subjects of acute interest in common and the achievements of May 28 are matters of heartiest congratulation. T. C. C.

The George Huntington Williams Memorial Lectures, inaugurated in 1897 by Sir Archibald Geike, have been continued this year by Professor W. C. Brögger, of the University of Christiania, who delivered at the Johns Hopkins University two lectures on The Principles of a Genetic Classification of the Igneous Rocks, and five lectures on The Late Geological History of Scandinavia, as shown by changes of level and climate in southern Norway since the close of the glacial epoch. His long and thorough investigation of the igneous rocks of the Christiania region, so varied in character, well preserved and finely exposed, has qualified him to speak with authority upon the subject of their genetic relations, and renders his judgment upon the general problem of the classification of igneous rocks of the first importance. Until the text of these lectures has been published, it will not be in place to discuss the conclusions enunciated by Professor Brögger. The lectures on The Late Geological History of Scandinavia were based upon recent field studies of the glacial phenomena of that region. In addition to their special scientific value, they illustrate the remarkable versatility and energy of Professor Brögger, whose substantial contributions to the paleontology and stratigraphy, the mineralogy and petrology of the Christiania region have already awakened the admiration of his fellow workers.

Professor Brögger also delivered his lectures on the Genetic Classification of Igneous Rocks at the University of Chicago to an appreciative audience of students and geologists, who assembled from various parts of Illinois and from Michigan, Wisconsin, and Minnesota. J. P. I.

Reviews

A Preliminary Report on the Geology of Louisiana. By GILBERT D. HARRIS, geologist in charge, and A. C. VEATCH, assistant geologist. Made under direction of State Experiment Station, Baton Rouge, La. Wm. C. Stubbs, Ph.D., director. [No place or date.]

This report is divided into three sections: I, Historical Review; II, General Geology, and III, Special papers.

In view of the important disagreements between the earlier writers upon Louisiana geology and the authors of this volume the historical review with which it opens is especially important and interesting. The full meaning of this review is only clear after one reads the second part and some of the third part of the volume. The lowest horizons represented are Cretaceous, and the earlier determination of these beds seems to have been based upon the occurrence of a single species, *Exogyra costata.* The present survey has been able to get together a a fairly good representation of the Cretaceous fauna of the state (p. 292–297).

The Mansfield of Hilgard, which was referred by Hopkins to the Jackson (p. 29–35) at the top of the Eocene, turns out to be Lower Lignitic Eocene (pp. 64–73), a horizon not hitherto known to exist in Louisiana. The conclusions reached in regard to the Cretaceous give us a new view of the general geology of the state. The dips and many other facts cited "indicate northeast-southwest local folds parallel to the old shore lines," rather than a northwest-southeast mountain chain (p. 62.) Of the Vicksburgh beds which some of the earlier writers thought they had found between Red River and the Sabine, Professor Harris says "we have found no trace of Vicksburg deposits west of Red River" (p. 90).

A part of the second section of the report is devoted to Economic Geology, and under this head are given valuable data regarding the salt, sulphur, and clay deposits of the state. Among the special reports are several of more than unusual interest. One of these is Mr. Veatch's paper upon "The Shreveport Area." Under this head he

treats at length "the great raft"—a subject of deep interest to geologists (pp. 160–173). He explains its origin, method and rates of growth and decay, and describes the effects of such accumulations and of their removal. He makes some interesting observations upon the lakes of the area, which he classes as: (1) cut-off or horseshoe lakes; (2) lakes of enclosure; and (3) raft lakes. The "raft lakes," it seems, have been attributed to a sinking of the land, but Mr. Veatch thinks they have been formed by the choking up of the former drainage by the accumulation of drift timber in old stream channels (p. 188). The activity of geologic agents in regions of such sluggish drainage has evidently not been realized hitherto, for here in a region at or close to its base level "Lakes have been formed and destroyed; streams have been formed and abandoned; waterfalls produced to destroy themselves; new streams formed out of parts of the beds of old ones and temporary reversals of the drainage systems have been affected" (p. 154). The articles on the Five Islands (pp. 213–262) is by far the most thorough and satisfactory that has yet appeared upon the remarkable salt deposits of Louisiana. The investigation of the clays by Dr. H. Ries is a valuable piece of work done by one of our best authorities on the subject.

Papers of paleontologic interest are given in the third section by Professor Harris upon the Natchitoches area, and upon the Cretaceous and Lower Eocene faunas of Louisiana. These papers are illustrated by seven beautifully prepared plates. Professor Harris also contributes a paper upon meridian lines, and another upon road making. This last subject is entitled to the serious attention of the people of Louisiana. That the geologists are unable to make the most of their time because of the bad roads of the state is to be regretted, and the geologists have our sympathy, but when many of these roads become such quagmires for several months of the year that traffic over them comes to a dead standstill, it is a matter that more or less seriously affects the prosperity and happiness of the entire population.

Arthur Hollick contributes a well illustrated and valuable article upon the Lower Tertiary plants from the northwestern part of the state (pp. 276–288, and 16 plates).

It is pleasant to see that Dr. Stubbs, the director of the State Experiment Stations, under whom the geological survey is being made, appreciates the fitness, ability, and enthusiasm of the men who are doing the work. Indeed it would have been difficult if not impossible to have

found a man better fitted than Professor Harris to take charge of the study of Louisiana geology. The problems of the stratigraphy of the state can be attacked successfully only by a careful study of the fossils. The promptness with which the report has been published is one of its many virtues. The work was begun in November 1898, and Professor Harris' letter of transmission is dated November 1899. Such promptness, however, sometimes has its disadvantages. It is doubtless responsible for several important typographical errors, for the awkward title-page that gives neither date nor place of publication, and for the unfinished condition in which the maps appear. Perhaps it is just as well that the geological map accompanying the report is credited to no one, for to no one is it a credit. With the exception of the maps the volume is well printed and tastefully bound; and the defects we may find in the mechanical part of the work are very small matters compared with the valuable contributions to science contained in the report.

JOHN C. BRANNER.

On the Lower Silurian (Trenton) Fauna of Baffin Land. By CHARLES SCHUCHERT, Proc. U. S. Nat. Mus., Vol. XXII, pp. 143–177, plates XII–XIV.

Any addition to our knowledge of the fossil faunas of the arctic regions is received with special satisfaction by those who are interested in the broader problems of palæontology, in which the facts of geographic distribution are of special moment. The present paper by Mr. Schuchert is one of the most important of such contributions to be found in our literature. It is devoted to the description and discussion of more complete collections of fossils from Sillman's Fossil Mount at the head of Frobisher Bay, than have previously been secured from that locality. Seventy species of fossils are recorded, eighteen being described as new. The fauna shows strong affinities with the Trenton fauna of the United States, especially with the fauna of that age as it is known in Minnesota, a large proportion of the species being common to the two regions.

The Trenton fauna has been recognized at various localities in the arctic regions, the strata containing it always resting unconformably upon the old crystalline rocks. No other Ordovician fauna has been recognized in the whole region save at one locality, on Frobisher Bay,

where a few species indicating a fauna of Utica age have been collected. In general the Trenton beds are followed immediately by strata containing a Silurian (Upper Silurian) fauna of Niagara or Wenlock age.

STUART WELLER.

The Glacial Palagonite-Formation of Iceland. By HELGI PJETURSSON, Cand. Mag. Copenhagen. The Scottish Geographical Magazine, May 1900, Vol. XVI, No. 5.

This appears to be a very important contribution to the history of Pleistocene glaciation. It opens up a new and very promising field, whose data are peculiar because of their association with volcanic phenomena. The author presents in much detail, and with apparent care and discrimination, evidence of glacial formations antedating the so-called "preglacial" lava flows, as well as others interstratified with the lava flows. After twenty-two pages devoted to description of details, illustrated by figures, the author draws the following important conclusions:

I shall not be surprised if this account of the occurrence of glacial deposits and striated rock surfaces in connection with the "palagonite-formation" of Iceland is received with incredulity. For myself, I could hardly believe the evidence when I first encountered it, and tried to explain it in every possible way other than by glacial action. But the glacial origin of the "breccias" could not be gainsaid. Not only did they present a characteristically morainic aspect, but they yielded numerous well striated stones, and in places were found to be resting upon grooved and striated rock surfaces. If the observations I have here recorded be accepted as fairly trustworthy, we cannot avoid the conclusion that glacial deposits, hitherto unrecognized as such, are largely developed in Iceland, or at all events in that part of the island which I have critically examined and referred to in these pages.

As I have had only a glimpse, as it were, into this very promising field of glacial research, I shall not attempt to deal with the glacial succession in Iceland. That must be left for future investigations to determine. Nevertheless there are several conclusions which seem to me obvious enough. Of these the most important, in my opinion, is that which has reference to successive glaciations. The facts advanced show that Iceland has experienced more than one glaciation before the ejection of the doleritic lavas and their subsequent smoothing and grooving by ice. How many separate glaciations the morainic breccias bear witness to is uncertain. But the repeated occurrence of four separate sheets or beds of morainic breccia seems to render it not improbable that there have been just as many separate glaciations during the

accumulation of the so-called palagonite formation. Even if we discard the evidence furnished by the lowest breccias (in which, it will be remembered, that notwithstanding their morainic aspect, no striated stones occurred), we have still the overwhelming evidence of glaciation supplied by the higher morainic breccias. But whether these indurated ground moraines represent three, four, or more glaciations, one or other of them must represent the epoch of maximum glaciation in Europe. The glaciation which left the older system of markings on the dolerite of Stangasfjall is, of course, of later date and may possibly represent the Mecklenburgian stage (Geikie) of northern Europe, and the first postglacial stage of glaciation of the Alps (Penck). It seems more than probable that a change of climate, corresponding to that which in the Alps depressed the snow line about 3000 feet, would bring about the total glaciation of Iceland. Indeed, a much less important change in the climatic conditions would suffice to do this. It is therefore quite possible that the younger system of striae marking the surfaces of the dolerites may be contemporaneous with that readvance of cold conditions which produced the local glaciers of the "Lower Turbarian stage" of Scotland, and those of the "Second postglacial stage" in the Alps.

[The second striated horizon in the moraine of Sudurnes (if it be not a striated pavement) may possibly indicate a third "post-doleritic" glaciation, but until additional evidence be forthcoming, this isolated observation must be left out of consideration.]

So far as I know, all that has been written on the glacial period in Iceland refers to the minor glaciations which supervened after the ejection of the doleritic streams of lava. I say minor glaciations, even although the country appears during those stages to have been totally ice-covered. But the mass of the "palagonite-moraines" is so very much greater than that of the loose accumulations of the later glaciations, that we may reasonably infer that the former are products of much greater ice-sheets. Moreover, the conditions of erosion and accumulation during successive glaciations seem to have differed at the same localities. Further, when we remember that the whole region throughout which the palagonite-formation occurs, has been extensively fractured and consequently has experienced many subsidences—and when we reflect that all these important deformations of the land surface took place subsequent to the accumulation of the uppermost morainic breccias, we are led to suspect that the area over which the older glaciations prevailed may have considerably exceeded that which now exists. Probably conclusive evidence on this point may be obtained by studying the directions of the oldest glacial striae all over the country, and more especially in the north.

It would probably also be of great interest to determine the relations of the Pliocene shell-beds near Húsavík, North Iceland, to the "tuff- and breccia-formation." As I have obtained a grant from the Carlsberg Fund,

Copenhagen, to enable me to continue these investigations, I hope to do so on the lines here indicated.

About 5500 square miles of the total area of Iceland are at present covered with glaciers. The country, therefore, would seem to be in a state of glaciation comparable to that obtaining in Scotland during the fourth glacial epoch as defined by Professor Geikie. Now, if Iceland were to be once more totally glaciated, should we term that final ice-invasion a separate stage of glaciation; or merely an oscillation of the existing glaciers? Would the present inhabited condition of Iceland be considered an interglacial epoch, or merely a stage of temporary glacial retreat?

Such considerations must be kept in view when we are discussing whether the old ground moraines described in this paper have been laid down by an oscillating ice-sheet or during separate glacial epochs.

In Búrfell two bottom-moraines are separated by 150 to 200 feet of basalt, on the striated surface of which the upper moraine reposes. Possibly, however, that basalt does not mark the lowest interglacial horizon.

To the next succeeding interglacial horizon probably belong the conglomerates of Stangarfjall, Bringa, and Hagafjall, which are supposed to be of fluviatile origin. Perhaps also the columnar dolerite of Stangarfjall should be included here. The existence of those conglomerates at such heights and so far inland suggests at least a very considerable oscillation of the ice-sheet. Moreover, we must not forget that the conglomerates in question are buried underneath masses of various volcanic products. [While some of the old gravel beds may well represent old river channels, in other places, as in Hagafjall and Bringa, they had more the character of lacustrine deltas or *cônes de déjection.*]

The next interval between two glaciations is that marked by the so-called "preglacial dolerites" which henceforward cannot claim to be more than interglacial. "At the time these preglacial lava beds were laid down, the country had pretty much the same essential contours that it has at present."[1] But when the uppermost of the "palagonite-moraines" (as in Berghylsfjall and Hagafjall) were laid down, the relief of the country, as we have seen, differed greatly from that which now obtains. In the interval of time that separates these morainic breccias from the eruption of the later lavas, the most radical changes in the contours of the country had been effected, chiefly perhaps by subsidence. The southern lowland of Iceland cannot date farther back than this interglacial epoch.

It is not improbable, indeed, that the essential contour lines or surface features of the whole island, so far as these are older than the later outflows of dolerite, came into existence during this interglacial epoch. We cannot tell at what particular stage the later dolerites were erupted, but we know

[1] Thoroddsen, Explorations etc., p. 35.

that the changes of relief which were effected during the interglacial stage in question were very much greater than those which have taken place since the outflow of the doleritic lavas. And yet these lavas have been glaciated more than once, and we do not know how long they had to wait for their first glaciation.

We seem therefore justified in coming to the conclusion that the two glaciations in question have not been the result of comparatively insignificant oscillations of an ice-sheet, but were really separated by a protracted period. The very occurrence indeed of the interglacial streams of lava over such great areas suffices to show how extensively the ice-sheet melted away. It seems to me highly probable that *all* the so-called "preglacial" lavas are in reality interglacial.

Furthermore, the evidence leads to the inference that the time which has elapsed since the last ice-sheet disappeared from the southern lowland of Iceland is very short as compared to the interglacial epoch that intervened between the first of the glaciations experienced by the dolerites and that next preceding it.

Whether the supposed marine deposit which underlies the glaciated lava on Tungufljót dates back to the closing stages of the interglacial epoch just mentioned, or whether it ought rather to be ascribed to an interval separating the two glaciations which are represented by the two systems of striae upon the surfaces of the later dolerites, future investigations must be left to determine.

No doubt many additional conclusions are suggested by the observations recorded in this paper, but I do not care to consider these at present. As already stated, the chief object of this paper is to point out that there exists in Iceland much hitherto unsuspected evidence of former glacial action. I am indeed sanguine enough to think it not improbable that the records of the glacial period have been more fully preserved here than elsewhere. For it is obvious that the conditions for the protection and preservation of glacial deposits have been with us somewhat exceptional. While in other lands, free from volcanic activity, each succeeding ice-sheet has partly destroyed and partly covered up the deposits of its predecessor, in Iceland the moraines have been greatly sheltered by the products of volcanic eruptions which overlie them. Moreover, crustal movements have contributed directly toward the same end by placing the old moraines beyond the reach, as it were, of succeeding glacial invasions. Not improbably, too, some rocks of the "tuff- and breccia-formation" may be due to the direct interaction of volcanic and glacial forces.

To this is added the discussion of some points of a more special and local nature. It is gratifying to learn that the investigation is likely to be continued.

T. C. C.

Fossil Flora of the Lower Coal Measures of Missouri. By DAVID WHITE. U. S. Geological Survey, Monograph XXXVII, 468 pp., 1900.

The coal floras are always of great interest. The present contribution is the most important that the central-West has seen since the appearance of Lesquereux's classic work of a quarter of a century ago. The title of the volume does not, however, express the real scope of the work. Most of the forms come from a single locality, near Clinton, in Henry county, Missouri, and from a single horizon — the Jordan coal. The latter is the lowest workable coal seam in the district and is only about 100 feet from the base of the Coal Measures.

While the greater part of the monograph is taken up with the minute descriptions of species, and discussions of the biological relationships of these, the chief interest to the stratigraphical geologist is centered in the data furnished for broad correlations.

Regarding the probable stage of the lower coals of Clinton in eastern sections, Mr. White says: "If we take Henry county, from which most of our evidence, both stratigraphic and paleontologic is drawn, as the stratigraphic type of the base of the Coal Measures of the state, and assume that the conditions are constant along the margin of the coal field in other counties, the evidence of the fossil plants, so far as they are now obtainable, appears to indicate the deposition of the lowest coals in the state at a time subsequent to the formation of the lower coals of the Lower Coal Measures of the eastern regions, including the Morris coal of Illinois, the Brookville and probably the Clarion coal of Ohio and Pennsylvania, yet perhaps earlier than the formation of the Darlington or upper Kittanning coals of the two states last named.

"The study of the distribution of the Henry county flora in this field shows its closest relations in coals D and E, locally known as the 'Marcy' and the 'Big' or Pittston coals. But in view of the fact that the E coal of the Pittston and Wilkesbarre regions seems to carry many types of a more modern cast, it is not likely that the Missouri stage is so high in the series as that coal. In the plants of the D coal, not only are a large part of the species identical with those from Missouri, but the flora as a whole is of a similar type. Compared, however, with the somewhat equivocal combined flora reported from the C coal, the material from the Mississippi valley appears on the whole fully as recent, while lacking many of the older types found at several

of the mines correlated by stratigraphy with that coal. Hence I am inclined to regard the plants from Henry county, Missouri, as more clearly contemporaneous with those in the roof of the D or 'Marcy' coal in the northern anthracite field, though they are possibly as old as the C coal."

The reference to the unconformity at the base of the Missouri Coal Measures is full of significance. "The transgression of the water level during the early Mesocarboniferous time has already been discussed by Broadhead, Winslow, and Keyes, the state geologists. The evidence of the fossil plants not only corroborates their views in general, but it also fixes the time of the encroachment of the sea on the old coast in the region of Clinton. The paleobotanic criteria indicates that the minimum time represented by the unconformity between Jordan or Owen coal and the subjacent Eocarboniferous terrane is measured by the period required for the deposition of the Pottsville and the Clarion group of the Lower Productive Coal Measures, a series of rocks reaching a thickness of over 1200 feet in portions of the anthracite regions, and exceeding 2400 feet in southern West Virginia."

The depositional equivalent of the unconformity at the base of the Missouri Coal Measures is even more important than Mr. White has indicated. As quite recently stated there is farther south in Arkansas, a sequence of Coal Measures beneath the basal horizon of the Des Moines and Missourian series combined. In reality the geological position of the Lower Coal Measures (Des Moines series) of Missouri appears to be well up in the median part of the Middle Carboniferous instead of at the base, as generally considered. Only in Missouri, about one half of the Middle Carboniferous is unrepresented by strata. This lacking series may be represented in Arkansas by upwards of 12,000 feet of sediments!

Attention is called in the monograph to some of the obstacles to accuracy in correlation and especially to the lack of standard paleobotanic sections. If ever there were opportunity of establishing a standard section of this kind it is in the Trans-Mississippian coal field. Plant remains occurs abundantly in many localities and at many horizons extending from the very base of Des Moines, up through the Missourian, into the so-called Permian. The monograph on the Missouri fossil floras considers chiefly one locality and one horizon. In Missouri alone there are no less than 150 known localities and 30 horizons for coal plants. In Iowa there are nearly as many more.

Kansas likewise offers an equally inviting field. If a single location yields up such prodigious possibilities as Mr. White has demonstrated what may we not expect from the rest of the vast field!

C. R. KEYES.

The Devonian "Lamprey," Palaeospondylus Gunni, Traquair. By BASHFORD DEAN (Mem. N. Y. Acad. Sci., Vol. II, Part I), 1899.

This elaborate memoir of thirty quarto pages and a plate drawn and lithographed by the author himself represent a vast amount of labor expended on minute, poorly preserved, and what would seem at first sight insignificant objects, found in the Caithness flags of Scotland. The fossil remains of *Palaeospondylus* are very unsatisfactory for study, and but for the peculiar interest attaching to them as supposed representatives of Palaeozoic Lampreys, they would hardly command attention. But zoölogists have been eagerly awaiting whatever enlightenment palaeontology might offer on the relations and descent of the Cyclostomes, and when Dr. R. H. Traquair announced his discovery of *Palaeospondylus* in 1890, it was hailed with delight as a definite clew to Cyclostome genealogy.

Dr. Dean observes: "Zoölogists were by no means unwilling to accept *Palaeospondylus* as a fossil lamprey; and they even found it a difficult matter to avoid going out in the road to give it a charitable reception. The fossil came, was seen, and was currently accepted. But time has gone by and suspicion come, and the thought is by no means comforting that the wrong prodigal may have been welcomed. Is *Palaeospondylus*, then, a veritable Cyclostome, or is it at least a provisional one?" Dr. Dean's purpose in investigating this question is a critical one, and he states that he has "attempted to analyze the results of preceding writers, to contribute some further data to our knowledge of the structure of this form, and to endeavor finally to determine what conclusions are justified in assigning a place to this fossil. After accomplishing all this in very satisfactory fashion, the author takes up the classification of fishlike vertebrates in general and introduces some novel changes, which will be referred to presently.

Dr. Dean's conclusion as to the Marsipobranch nature of *Palaeospondylus* takes the form of a more emphatic denial than ever (see his previous paper in *Proc. Zoöl. Soc.*, April 1898) that it can be regarded

even provisionally as a fossil lamprey. Dr. Traquair's objection that if *Palaeospondylus* be not a Marsipobranch it is impossible to refer it to any other existing group of vertebrates, Dr. Dean disposes of by boldly placing it in a new class by itself, elevating the order Cycliae, which Gill created for it, to that rank. Such a course may strike one as rather startling, perhaps, but it is certainly effective. An alternative proposition which Dr. Dean suggests may be more acceptable to some ichthyologists "is to place it with *Coccosteus* as doubtfully its larval form." Although there is considerable reason for regarding the variations in this small form as the early stages of some larger chordate, yet there is no direct proof that the adult form was an Arthrodire; hence this association would have to be at best only provisional, and, in the author's opinion, is inexpedient. As to the relations of newly exalted Cycliae to other classes, we are left as much in the dark as ever. Some very excellent figures of the fossil forms are given, together with a diagrammatic restoration.

Very interesting, indeed, are the author's views on the systematic arrangement of the early forms of fishlike vertebrates and fishes proper, with which the paper concludes. Amongst the latter the Chimaeroids are reduced again to the rank of an order instead of a subclass, principally as the result of Dr. Dean's recent embryological investigations, and the Dipnoi are reduced from class rank (Parker) to that of a subclass. *Acanthodes* and *Cladoselache* are grouped together under the primitive Elasmobranch order Pleuropterygii.

Turning now to the most primitive of all chordates, Dr. Dean elevates the Ostracoderms and Arthrodires each to the rank of an independent class, the former with its customary triple subdivision, but the latter separated into two new divisions, Arthrodira proper and Anarthrodira, which rank as subclasses. On the ground of their lacking a mandibular arch and paired limbs, the Ostracoderms were denied by Cope, and following him by Smith Woodward, and others, to be fishes at all, but organisms far removed from the latter, called "Agnatha." The origin and relations of the Ostracoderms are at present among the most important and fascinating questions of palaeichthyology. Dr. Traquair, in an extremely valuable memoir of last December[1] refuses to believe that these forms are Agnatha, declaring Cope's view to rest entirely on negative evidence, and preferring to look upon the lowest

[1] Report on Silurian Fishes (Trans. Roy. Soc., Edinburgh, Vol. XXXIX, Pt. III), 1899.

Ostracoderms "as having definitely split off from the Elasmobranchs, from which they doubtless originally came." Dean believes in a wider separation, however, from the groups represented by recent forms; but regarding the differences between Ostracoderms and Arthrodires, he makes the following significant remark: "A renewed examination of the subject has caused me to incline strongly to the belief that Pterichthys and Coccosteans are not as widely separated in phylogeny as Smith Woodward, for example, has maintained. But as far as present evidence goes, they appear to me certainly as distinct as fishes are from amphibia, or as reptiles are from birds or from mammals" (p. 24). The reference to Smith Woodward bears, of course, on the recognition of Arthrodires by that author as an order of Dipnoi.

Whatever may be thought of the class Cycliae, there is no question but that Dr. Dean has scored an advance by elevating the Ostracoderms and Arthrodires to a higher rank and placing them in close proximity to one another. A separation of the two classes is rendered necessary of course, thus prohibiting the revival of McCoy's "Placodermata," by the absence of "jaws," endoskeletal structures, and paired limbs in the first-named group. Nevertheless the two classes have a number of points in common, and should we be led to infer with Traquair an Elasmobranch derivation of the Ostracoderms, it would be natural to trace Arthrodires to the same source. Whether there were really "Agnatha," and how far the archaic fishlike vertebrates were removed from the groups represented by living forms, must be left for future study to decide. Or possibly we may never have the solution of these perplexing problems.

In one minor point only the reviewer finds himself in disagreement with Dr. Dean, and this relates to the subdivision of Arthrodires (or "Arthrognaths," to use his new term) into Arthrodira proper and Anarthrodira. The latter includes *Macropetalichthys*, *Trachosteus*, *Mylostoma*, and certain transitional forms which the author promises shortly to describe. When the cranial and body armoring of *Trachosteus* and *Mylostoma* are made known, their position may become evident. At present we are acquainted only with the cranial osteology of *Macropetalichthys*, and this is so far different from that of typical Arthrodires that in the reviewer's opinion it cannot be retained in the same class. As typical of an independent family, it had best be removed with the Asterosteidae to a position amongst the Ostracoderms, as we certainly do not wish to make of it an independent class. The comparisons between

this form and the cranial and dorsal shields of Arthrodires indicated by Cope and the reviewer a few years ago were based upon a misconception of the septum dividing off the so-called "nuchal plate;" but in reality no homology exists between arrangement of cranial plates or the sensory canal system of this form and those of Arthrodires. No plates corresponding to the dorsal or ventral armoring of *Coccosteus*, etc., are known, nor is there any evidence of a lower jaw, of paired fins, neural or haemal arches, nor any form of dental plates attached to the roof of the mouth. Finally, the bone-structure is perceptibly different from that of typical Arthrodires, and the under side of the head is unparalleled in the latter group. This form is certainly worthy of careful reinvestigation.

The whole matter of Dr. Dean's Anarthrodira, is, however, of subordinate importance as compared with his main theme, which is admirably treated; and palaeontologists will be sure to appreciate his clear exposition of the same, supplemented as it is by a complete bibliography and expertly drawn figures.

C. R. EASTMAN.

Some High Levels in the Postglacial Development of the Finger Lakes of New York. By THOMAS L. WATSON. With 30 figures and 3 maps. The figures being mostly full page half-tones, maps, and diagrams. Appendix B. Report of the Director of the New York State Museum, 1899.

Dr. Watson presents in a very clear and interesting manner the results of the earlier works of other investigators and of his own extended observations on the high level terraces and water marks in the Finger Lakes region. He finds that at the time of maximum advance of the "ice of the second glacial period" (by which he probably means the early or late Wisconsin of some writers) the ice front extended to and beyond the present divide which separates the waters draining northward into the St. Lawrence and those of the Chemung-Susquehanna draining to the southward. The preglacial valleys now occupied by the Finger Lakes were entirely overridden by the ice but were not completely filled with the glacial débris, so that as the ice front began to retreat and had drawn back to a position north of the divide there was formed, in the valleys, numerous local glacial lakes which drained southward through several channel ways. These channel

ways were at different levels for the different lakes and as the ice front drew back to the northeast, the several local lakes coalesced into fewer larger bodies of water and the higher outlets were abandoned in succession until finally there was but one body of water, Lake Newberry, with a single outlet to the southward. This outlet was finally abandoned when the waters of Lake Newberry fell to the level of and coalesced with those of Lake Warren. At last the opening of the St. Lawrence and the lowering of the Lake Iroquois left the waters of the present Finger Lakes in the old valleys, held back by drift barriers. The evidence for this sequence of events, which the author traces with much detail, is found largely in the high level delta deposits made by the tributary streams in the temporary glacial lakes at the levels of the southern outlets which mark the successive stages of water levels. Dr. Watson's map of the temporary, local, glacial lakes of the Finger Lakes region suggests that under similar relations of ice front to topographic form, such as undoubtedly prevailed farther westward in New York and through northern Ohio, the results of glacial action would be much the same and that if we are to arrive at a correct interpretation of the sequence of events during the Pleistocene it will be through the detailed study of many limited areas in the careful painstaking manner shown by the work of Dr. Watson. Such work cannot be too highly commended.

W. G. T.

Twentieth Annual Report of the U. S. Geological Survey, Mineral Resources of the United States, 1898. Washington, D. C. 616 and 804 pages.

The annual report on the mineral resources for 1898 like its predecessors contains much valuable statistical and descriptive matter on the different mineral products of the United States. The data in the present report have been brought up to the close of 1898 and, as has been customary since 1894, when this publication was first made a part of the annual report, along with the statistical matter there is included valuable information on the industrial uses, improvements on ore reduction, new developments, distribution of ores, chemical analyses, and other data concerning the different products. The statistics on some of the products are given in great detail, thus nearly one hundred pages are devoted to a discussion of the iron ores and the American and foreign iron trade, which is not an undue proportion of space

when we consider that the value of iron for 1898 was 116.5 millions of dollars against 227 millions for all the other metallic products. Likewise 314 pages are given to the coal and coke industries but the value of the coal alone is 208 million dollars against 145 millions for all other non-metallic products. The total value of all the mineral products for 1898 is $697,820,720 which is an increase over the preceding year of $66,966,791 or 10.62 per cent.

Some of the more important special topics discussed are (1) the history of gold mining and metallurgy in the southern states by H. B. C. Nitze; (2) the characteristics, uses and domestic and foreign production of manganese ores by John Birkinbine; (3) the slate belt of Eastern New York and Western Vermont by T. Nelson Dale; (4) more than 100 pages of analyses and tests of building stones collected from various sources by Wm. C. Day and classified and arranged by states; (5) a brief reconnaissance of the Tennesse phosphate fields by C. Willard Hayes; (6) the mica deposits in the United States by J. A. Holmes; and (7) the mineral resources of Porto Rico by Robert T. Hill, and H. B. C. Nitze.

T. C. H.

Les Charbons Britanniques et Leur Épuisement. By ED. LOZÉ. Two volumes. Paris, 1900.

This work is an exhaustive treatise on British coals, comprising a discussion of their history, exploitation, production, consumption, geological occurrence, value, qualities, classification, utilities, and exportation. The work as whole is divided into four parts. Part one presents a general discussion of the geography and inhabitants of Great Britain and Ireland; their social, political, and economic conditions; the influence of the coal industry on economics, navigation, naval power, and the national debt; the geology of the British Isles; the history of coal production and the statistics bearing on its production and consumption.

Part two furnishes a description of the coal beds of the United Kingdom and discusses their importance and productiveness. This is followed by a series of chapters on the industrial and commercial geography of the Islands, constituting the third part of the work. The fourth part treats of the productiveness of the coal mines, and the probable time of depletion.

It is thought probable that coal was first used in Britain by the early Bretons, but direct evidence of it is wanting. However, it is known to have been used by the Roman invaders, as cinders and coal ashes have been found in the ruins of the Roman houses. Not much is known of the coal industry from the time of the Roman invasion until the beginning of the thirteenth century when it is referred to in certain land grants. The first mines were located in the vicinity of Newcastle. By the year 1379 coal had become of sufficient importance to make it an object of impost. By the beginning of the sixteenth century the production had reached an average of a million tons per year, and the total production from that date to 1866 is estimated to be 850 million tons.

The principal coal beds of the United Kingdom occur in the Coal Measures or upper part of the Carboniferous series. According to Hull the Lower Carboniferous has a threefold division: (1) the lower schist group, (2) the Mountain limestone, and (3) the Yoredale group. The Upper Carboniferous is divided into (1) the Millstone grit, (2) the lower Coal Measures, (3) the middle Coal Measures, and (4) the upper Coal Measures. The last three divisions contain the productive coal beds. The work is accompanied by maps locating accurately the known coal areas and giving the probable extent of the undetermined ones.

The coals of Britain are classed under the heads of:

1. Lignites, containing 67 per cent. of carbon and 26 per cent. of oxygen.
2. Bituminous coal, containing 75 to 90 per cent. of carbon and 6 to 19 per cent. of oxygen.
3. Steam coal, a sort of semi-anthracite.
4. Cannel coal, containing 40 per cent. of volatile matter and being rich in hydrogen.
5. Anthracite coal, containing 93 to 95 per cent. of carbon and 3 per cent. of oxygen with 2 to 4 per cent. of hydrogen.

The total exportation of coal from the British Isles in 1898 was 35 million tons, which was a decrease over the preceding year of about 300,000 tons. The importation of coal for 1897 was only 9454 tons. The amount of coal consumed per capita in 1898 was 3.867 tons.

The author discusses the estimate made by the Commission of 1870, that the coal resources of the United Kingdom are 80 billion tons, and that at the present rate of depletion (2 million tons per year)

the total exhaustion will take place in four hundred years; and arrives at the conclusion that the time may be even less than that given by the Commission. That the day of complete depletion will come, the author is assured, and when it does come "the historian of a powerful empire will terminate, very probably, the narrative of a remarkable epoch with these words, *finis Britannae*." W. N. LOGAN.

Cape Nome Gold Region. By FRANK C. SCHRADER and ALFRED H. BROOKS. United States Geological Survey, Special Report, 56 pp. Washington, 1900.

The Cape Nome gold field which has recently occasioned so much excitement is of special interest geologically on account of being the most noteworthy modern beach placers known. The type of ore deposits to which these Alaskan beds belong has long been recognized, but no bodies of this kind have ever proved so rich. Ancient deposits of the same origin are not unknown. Such are the Witwatersrand blanket of the Transvaal and the Napoleon Creek conglomerate in Alaska.

The Nome district is on the southern shore of the Seward peninsula in a little known part of northwestern Alaska. "The beach rises gradually to a sharply cut bench, a hundred to two hundred yards from the surf. From the edge of this terrace, which is about twenty feet high, the moss-covered tundra extends inland, rising uniformly about two hundred feet in four or five miles, when it merges into the highland belt."

The bed-rock of the region is composed of limestones and phyllites or mica schists interbedded, with some gneiss. Igneous rock is of rare occurrence. Over this foundation lie the unconsolidated gravels with gold-bearing zones. The authors emphasize the fact that during the deposition of the gravels and sands the conditions were not materially different from those of today, except that the land stood at a lower elevation relatively to the sea. "There is no evidence whatever of glacial action in the region, and the popular idea that the gravels were brought to their present position by ice action is entirely erroneous."

The gold-bearing deposits are grouped into gulch-placers, bar-placers, beach-placers, tundra-placers, and bench-placers. The gulch and beach placers are the most productive. During the past year (1899) the production was three million dollars.

The gold is usually rounded and often smoothly polished. It is not evenly distributed through the gravels but gathered in zones. In

washing the pay-streaks the heavy minerals garnet and magnetite are concentrated along with the gold. The first forms "ruby sand" and the latter "black sand."

Good prospects for gold occur in many other places in the Seaward peninsula. "The geographic portions of some of the different localities suggest that they may belong to the same gold belt. The facts known to us, however, are not sufficient to prove this; and it must simply be regarded as a working hypothesis. Should subsequent development and investigation show that the gold of all of these districts of Seward peninsula is derived from the same series of rocks, this gold-mining region will embrace an area of at least 5000 to 6000 square miles. If this proves to be the case, it does not by any means follow that the entire belt will contain workable gold deposits. We should rather expect to find the gold confined to certain zones within the belt."

The report is accompanied by a number of excellent views of the region. This preliminary report gives us a good idea of just what the visitors and prospectors may expect when they reach the Cape Nome region. Scientists will await the appearance of the final report with interest. C. R. KEYES.

Syllabus of Economic Geology. By JOHN C. BRANNER, Ph.D., and JOHN F. NEWSOM, A.M., Second Edition, 1900, pp. 368. Plates and Diagrams.

This volume is a syllabus of a course of lectures on economic geology given by the authors at Leland Stanford Junior University. It is intended primarily for the student, but will also be found a most valuable guide to anyone interested in the various branches of economic geology. It begins with a general list of the more important works on economic geology, and of the periodicals relating to this subject. After this are a few introductory remarks on geology in its relation to various economic subjects, including mining, agriculture, forestry, manufacturing, industries, art, roads, railways, migration, etc., followed by a brief synopsis of geological sections, maps, surveys, etc., from an economic standpoint; a summary of economic geological products and their various classifications as proposed by different authors; rock-cavities; the formation of ore bodies; and the features of ore deposits. This general part of the subject takes up the first fifty pages, and most of the rest of the volume treats of different kinds of ore deposits and

other deposits of economic value, including iron, chromium, manganese, copper, tin, cobalt and nickel, zinc, lead, silver, gold, platinum group, tungsten, molybdenum, antimony, bismuth, cadmium, arsenic, mercury, precious stones, coal, graphite, petroleum, natural gas, ozokerite, asphalt, salt, soda, borax, niter, soda niter, barytes, sulphur, iron pyrites, feldspar, fluorite, mineral pigments, abrasives, marble, limestones other than marble, building stones in general, kaolin, clay, bauxite, aluminum, glass sand, refractory materials, natural fertilizers, monazite, road materials, soils and water. Under each of these headings is given a brief account of the chemical and mineralogical character of the material under discussion, its mode of occurrence, its distribution, and other technical or commercial data of interest, together with a list of the more important literature on the subject. The volume closes with a few very pertinent remarks and suggestions on the subject of reports on mining properties, and with a list of references to works on mining law.

The lists of literature given in the volume contain the more important publications on the different subjects treated, and though, as the authors themselves say, they have not attempted to make the bibliography complete, yet the references which they have given are all useful and will be found to be a ready guide to those who wish to follow up the subject further. For the student, this system is especially useful, as he gets in the syllabus only references to the most important literature, and is not encumbered with what is not immediately necessary for his purposes; at the same time he has the means of finding any other literature that may exist on the subject. A very useful feature of the volume are the blank pages which alternate with the pages of printed matter, thus giving means of inserting further references to literature or making short notes, etc.

The volume contains 141 illustrations including geological sections, sections of ore bodies and of mines, statistical tables, etc., all of which add greatly to the usefulness of the work as they make it possible in a condensed form to understand clearly the various subjects discussed.

The volume relates mostly to the economic geology of the United States, but that of foreign countries is occasionally mentioned. It covers a wide field in a form which though condensed is sufficiently full to answer all the purposes for which it is intended. It is a most valuable work, and the thanks of all interested in economic geology are due to the authors who have prepared it. R. A. F. P., Jr.

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THE

JOURNAL OF GEOLOGY

MAY—JUNE, 1900

METHODS OF STUDYING EARTHQUAKES

I PROPOSE in this paper to consider the methods of studying earthquakes of a moderate degree of intensity, *i. e.*, those which disturb areas of not more than a few thousands of square miles, and which as a rule are too weak to cause any very serious damage to property. Of such earthquakes, about ten or twelve are felt every year in Great Britian; the majority are slight, but once in four or five years a shock will occur that is noticed over a district containing more than 50,000 square miles. The methods of investigation do not, however, vary much in these cases; but, as they can only be applied with success in rather populous countries, it seems possible that they may be as useful in certain parts of the United States as they have already proved to be in the British Isles.

The whole aim of an earthquake inquiry has been widened during the last ten years. It is no longer merely a question of determining the position of the epicenter, though this is still one of the first problems to be solved. We have to ascertain not only the place where a fault-slip occurred, but the direction of the originating fault, its hade, and the nature of the movement which gave rise to the shock; for the earthquake is but a passing incident in the growth of a fault. It is the transitory effect on the surface of a displacement, within the earth's crust; and

the displacement, rather than its effect, is the more important subject for investigation.

For determining the position of the epicenter, three methods have been employed, depending respectively on observations of the direction, time of occurrence, and intensity of the shock.

The first method was suggested by Mallet, and used by him in studying the Neapolitan earthquake of 1857, and by a few other seismologists who have followed in his steps. Later on, the method fell into disrepute; and, so far as it depends on individual observations of the projection or fall of bodies, etc., it must, I think, be regarded as unreliable. But, if the number of observations be large, the average of all the records in one place may give a close approximation to the true direction. This was first shown by Professor Omori for the Tokio earthquake of 1894. In that city, the earthquake, besides a number of minor vibrations, consisted of a single great oscillation, the maximum displacement in which was 73^{mm} in the direction W. 20° S. and E. 20° N. Many columns and monuments were overthrown, and especially a large number of "Ishidoro" or stone lamp-stands placed in gardens. Professor Omori measured the directions in which 245 bodies fell in different parts of the city, 144 being "Ishidoro" with circular bases. The directions are extremely varied, and at first sight appear to be subject to no law, but the mean direction given by all the observations is W. 19° S. and E. 19° N.[1] If we take only the 144 "Ishidoro" with circular bases, and regard all the determinations of the direction as of equal value, we find the mean direction to agree exactly with that given by the seismographic record, and to have a probable error of less than two degrees.

The study of the Hereford earthquake of 1896 led to a somewhat similar result. In this case, observations of overturned bodies were not available, and the estimates of the direction were all made from personal impressions. They are extremely rough, few of the observers referring to more than the eight principal points of the compass. Moreover, as a general rule, the apparent

[1] Bull. della Soc. Sismol. Ital., Vol. II, 1896, pp. 180–188.

direction of the movement was nearly perpendicular to one of the principal walls of the house in which the estimate was made. But this very fact, which seems to render the observations valueless, turns out to be of service; for the impression of direction is most distinct in buildings whose walls are perpendicular to the true direction of the shock. The majority of the records naturally come from such houses, and thus the average of all the estimates collected gives a nearly accurate result. The mean directions for London and Birmingham, for instance, intersect almost exactly in the epicenter, and those for several counties pass within a short distance of this spot.[1] Thus the method of directions, if we give a somewhat different meaning to it from that intended by Mallet, may determine the position of the epicenter with a close approach to accuracy.

It is doubtful whether the second method, depending on time-observations, can ever lead to any but very rough results. The chief reason for this is the difficulty of determining the time accurately to within a few seconds. But, supposing this were possible, there is also the uncertainty whether it is the same phase of the motion which is timed by observers in different places; for the vibrations which appear strongest to different persons do not necessarily come from the same part of the focus, and may come from parts which are separated by a distance that is considerable when compared with the dimensions of the disturbed area. While good time-observations may enable us to determine the surface velocity of the earth-wave, they can hardly, unless very numerous, afford information of much value with regard to the position of the epicenter, and still less with regard to the depth of the focus.

There remains the third, and by far the most fruitful, method of inquiry — that which is founded on the intensity of the shock.

[1] "The Hereford Earthquake of 1896" (Cornish Bros., Birmingham,) pp. 265–270. I have applied this method to the Charleston earthquake of 1886, for which Captain Dutton's well-known memoir supplies the materials. Here it was necessary to group together observations in separate states, the areas of which are to large to give good results. But, in several cases, the mean direction so obtained differs only by a few degrees from the line joining the center of the state to the epicenter.

By means of an arbitrary scale, for which we are indebted to the joint labors of Professors M. S. de Rossi and F. A. Forel, the intensity at any place may be expressed according to the mechanical effects produced by the earthquake. A series of isoseismal lines may then be drawn, each surrounding the places where the shock was of a given intensity and excluding those where it was distinctly less; and if the series is complete, the innermost isoseismal enables us to determine the position of the epicenter, generally with a close approach to accuracy.

But the method of intensities does more than this. When the isoseismal lines are carefully drawn—and this is only possible roughly elliptical in form; their longer axes are parallel or nearly so, but they are not coincident. In my report on the Hereford earthquake (pp. 216–218), it is shown that this must be the case when the earthquake is due to the friction generated by a fault-slip; for the focus is then a surface inclined to the horizon. Moreover, the focus and relative positions of the isoseismal lines are indices of the direction and slope of the fault-plane. The longer axes of the curves are parallel to the fault-line or strike of the fault; and, on the side toward which the fault slopes, the isoseismal lines are further apart than on the other side of the fault-line, except at great distances in the case of a strong earthquake, when the inequality is reversed.

I can give no better example of a slight earthquake than that which occurred on April 1, 1898, in the south of Cornwall.[1] The positions of the principal places where it was felt are shown in Fig. 1, but the coast-line is omitted in order to simplify the diagram. The continuous curves represent the isoseismal lines of intensities 4 and 3 of the Rossi-Forel scale; and their forms and relative position show that the fault-line must run from E. 33° N. to W. 33° S.; and that the fault must hade to the southeast.

The latter inference is corroborated by the study of the sound-phenomena, to which the two dotted lines relate. The outer of these lines represents the boundary of the sound-area,

[1] Quart. Jour. Geol. Soc., Vol. LXVI, 1900, pp. 1–7.

while the inner one separates those places where the sound was loud from those where it was distinctly fainter. As the more prominent sound-vibrations appear to come from the upper margin of the seismic focus[1], the northwesterly shift of the sound-curves with respect to the isoseismal lines implies that the fault hades in the direction opposite to them.

One of the most interesting features of British earthquakes, though it is by no means confined to them, is the double nature of the shock. At many places there are two distinct series of vibrations separated by a brief interval of absolute rest and with a large number of observations—they are as a rule quiet. This was the case during the Hereford earthquake of 1896 nearly all over the disturbed area. As a rule, however, a weak tremor and a faint rumbling noise are observed during the interval at places near the epicenter ; while at considerable distances from the origin these become imperceptible, and the shock appears to consist of two detached portions. The double shock is chiefly characteristic of strong or severe earthquakes but there are several slight ones in which it has been observed. Attempts have been made to explain it by the reflection or refraction of the earth-waves at the bounding surfaces of strata, or by the existence of longitudinal and transversal vibrations. But the wide distribution of the places where the double shock is observed and the fact that the relative nature of the two parts of the shock is not constant all over the

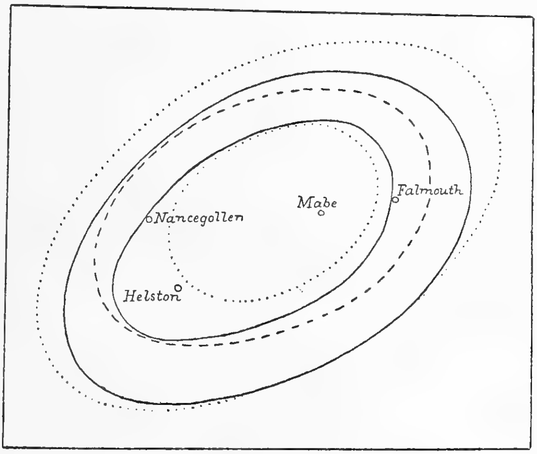


FIG. 1.

[1] Phil. Mag., Jan. 1900, pp. 66–70.

disturbed area, are conclusive against any theory based on the assumption of a single initial impulse. In the cases which have been investigated, there can be no doubt, I think, that there were two distinct foci, and that the impulses at them were nearly, but not quite, simultaneous. In the Charleston earthquake of 1886, Captain Dutton was able to locate the two foci; and this has also been done in several British earthquakes.

There appear, however, to be two distinct classes of earthquakes in which a double shock is observed; of which the Cornish earthquake of 1898 and the Hereford earthquake of 1896 may be regarded as respective types. The chief outward difference consists in the length of the interval between the two parts of the shock. In the first case, the interval was a quarter of a minute or more in length; in the second, it varied from a few seconds to zero. The Cornish earthquake consisted in reality of two successive earthquakes originating in nearly the same region of the fault, and the foci were overlapping. The Hereford earthquake was a true *twin* earthquake, the foci were completely detached; but the impulses at the two foci were due to the same initial stress, and the impulse at the second was in no way a consequence of that at the first, for it took place before the earth-wave from the first had time to reach the other.[1]

The two parts of a twin earthquake differ as a rule in intensity, in duration, in the period of their vibrations, and possibly in other ways. The distribution of the places where the first part was stronger, etc., than the second, enable us to determine at which focus the initial impulse was the more powerful and which was first in action. In the Hereford earthquake, the region in which the first part of the shock was stronger, of greater duration, and consisted of slower vibrations, was separated from that in which the same features characterized the second part, by a hyperbolic band, passing between the two foci. Within this band the

[1] The explanation of the double shock given in the report on the Hereford Earthquake (p. 295) I believe to be generally true for twin earthquakes; but I propose to consider the subject more fully in another paper.

two parts of the shock were superposed, showing that the impulses were not simultaneous, and that the focus within the concave part of the hyperbola was last in action. In the Cornish earthquake of 1898, the interval between the two parts of the shock was so great that the first and weaker part was felt all over its disturbed area before the second was felt at its epicenter. Consequently, the broken line in Fig. 1, which surrounds all the places where the double shock was observed, constitutes the boundary of the disturbed area of the earlier portion.

In studying an earthquake, there will be found on almost every point considerable conflict in the evidence collected. Much of it is no doubt due to inaccurate observation, part to a misunderstanding as to the information desired. It is in the records of the sound phenomena that the greatest diversity exists, a diversity which can hardly be ascribed to inattention or defective observation, and which can only be explained completely on the supposition that the sound is so deep that some persons are incapable of hearing it. Near the epicenter, the strength of the sound-vibrations is so great that they are audible to nearly every person, but the percentage of observers who hear the sound decreases rapidly towards the boundary of the sound-area. The variation in audibility throughout the sound-area may be illustrated by means of isacoustic lines. The percentage of auditors of the sound among those observers within a given area who felt the shock is taken to correspond to the center of the area in question, the lines joining adjacent centers are divided so as to give points where the percentage would, on the hypothesis of uniform variation, have certain definite values, say 90, 80, 70, etc., and lines are drawn through all points where the percentage marked is the same. The isacoustic lines for the Hereford earthquake of 1896 are represented in Fig. 2. The axis of the isoseismal lines runs almost exactly northwest and southeast, and the points of greatest extension of the isacoustic lines lie on a curve (broken in the figure) which coincides almost exactly with the hyperbolic band referred to above. The explanation of the peculiar distortions of the isacoustic lines is that, along this band, the

sound-vibrations from both foci were heard simultaneously, and the additional strength thus rendered them audible to an increased percentage of observers.[1]

The variation of other phenomena may be similarly represented — such as the frequency of comparison of the sound to

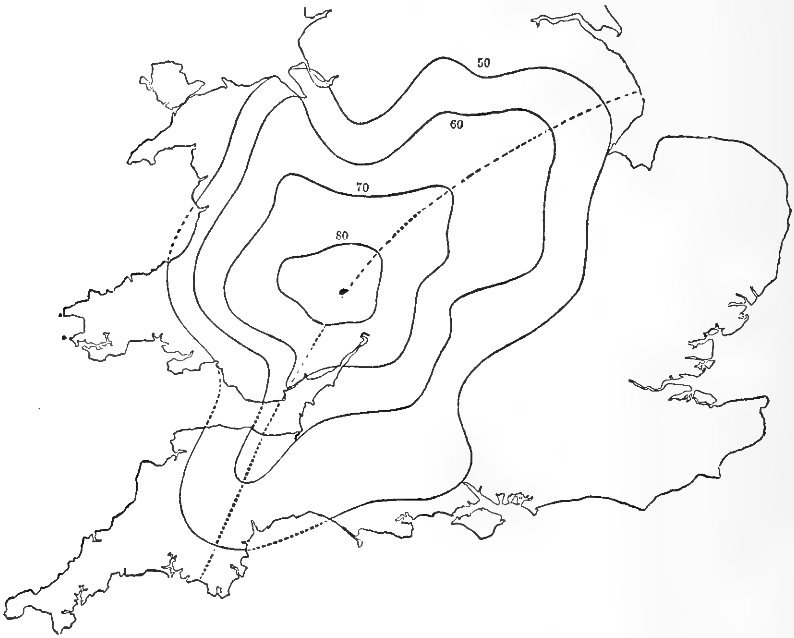


FIG. 2.

definite types, the audibility of the sound-vibrations before and after the shock is felt, the audibility of the loud crashes heard when the sound is loudest, etc. The method of course requires a very large number of records for its employment; but, in no other way, can the influence of erroneous or defective observations be so successfully eliminated.

CHARLES DAVISON.

KING EDWARDS HIGH SCHOOL.

[1] Phil. Mag., Jan. 1900, p. 43.

GLACIAL GROOVES AND STRIAE IN SOUTHEASTERN NEBRASKA[1]

NEBRASKA is so close upon the western as well as the southern limit of the drift that evidences of glacial action which might be commonplace elsewhere are rare and interesting here. The mere fact that glacial grooves and striae have been found seems worthy therefore of mention. Glacial drift, readily recognizable as such, does not extend far west of the 97th meridian, and in but one place in the state, on the Dakota-Nebraska boundary, does it reach the 98th meridian. East of the 97th meridian it is distinct and unmistakable, and it may be offered as a safe statement that probably in no other state is the glacial drift so generally recognized as such by the mass of the people. This is due to the presence of numerous bright red and purple bowlders of Sioux quartzite. They are unmistakable, and it is generally known that they have been transported from the region of Sioux Falls in South Dakota, and scattered along the eastern border of Nebraska, and south into Kansas. Bowlders of Sioux quartzite twenty feet in diameter are to be found as far south as the Nebraska-Kansas line. A heavy mantel of drift, overlaid by a hundred feet or so of loess, so effectually conceals the rocks that exposures are rare, and striations and similar evidence of glacial action, which may be common enough in fact, are not seen. The first were found by the author in 1894 on a slab of Carboniferous limestone in the old Reed quarry one mile northeast of Weeping Water.

Though not found exactly in place it was unmistakably native rock. The ledge from which it came has just been found by Mr. E. G. Woodruff (Univ. Nebr. 1900). It is a narrow ledge perhaps 300 feet long by five to six feet wide, leveled, smoothed, and striated throughout. The grooves and striae run south eleven degrees east. One groove, the most conspicuous

[1] Paper read before the Nebraska Academy of Science, December 2, 1899.

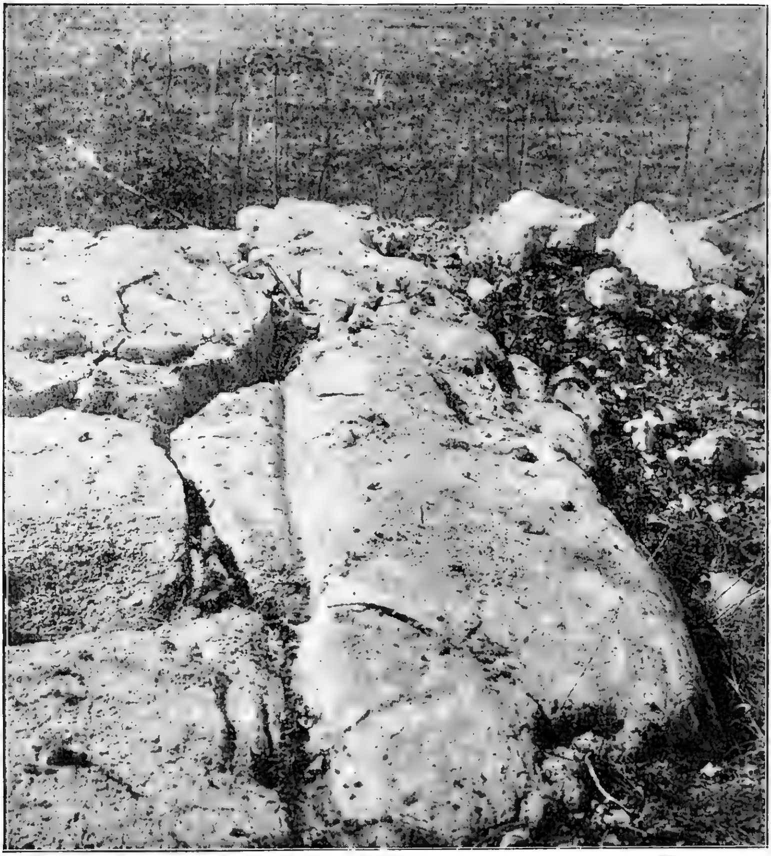


FIG. 1.—Glaciated surface, carboniferous limestone, Weeping Water, Nebraska, badly shattered by a blast, yet plainly showing striae and grooves. The central groove varies from three to four inches in width, and is about one and one quarter inches deep, and runs south 29° west. From a photograph by the writer.

noted, being three inches across and one and a quarter deep, ran south twenty-nine degrees west. There were numerous ragged grooves varying from one quarter to one half inch in depth, and innumerable closely crowded parallel striae. The whole surface was reduced to a plane, portions of which were well polished. Upon it rested a thin layer of drift consisting of a little clay, numerous large pebbles and an occasional bowlder of Sioux

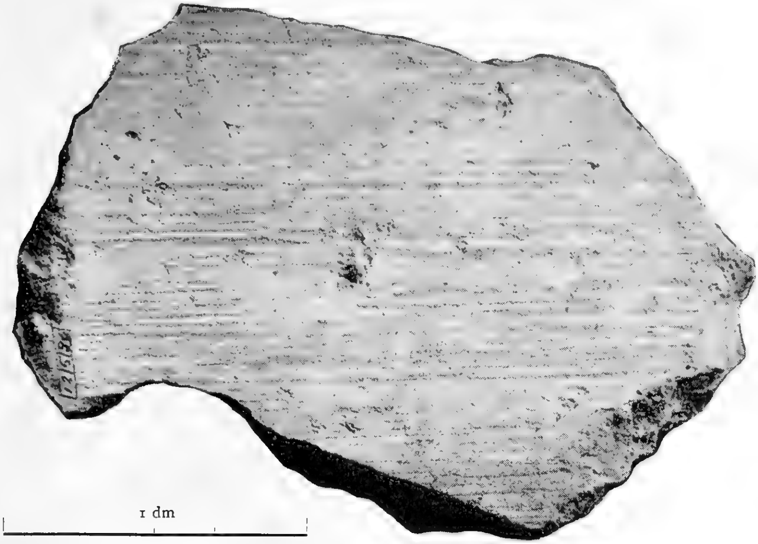


FIG. 2.—Cabinet specimen (7 by 10 in.) in the State Museum of Nebraska, showing planed surface and glacial striae on carboniferous limestone, Weeping Water, Nebraska. Striae run south 11° east. Photograph of a specimen procured by the writer in 1894.

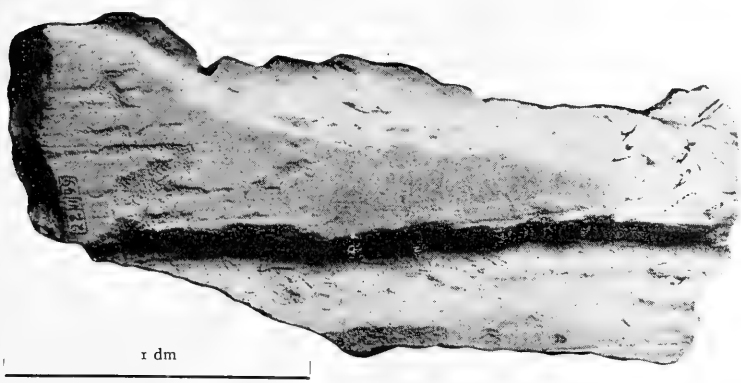


FIG. 3.—Cabinet specimen (7 by 10 in.) in the State Museum of Nebraska, showing planed and polished surface, striae, and a small glacial groove, carboniferous limestone, Weeping Water, Nebraska. Photograph from a specimen secured by Mr. E. G. Woodruff, fall of 1899.

quartzite, the largest noted being about three feet through. The drift is thin here, nowhere exceeding a foot or two, as far as observed. Upon this thin but unmistakable layer of drift lies some twelve to fifteen feet of loess.

Two very tortuous miniature channels with polished and scored sides were noted. The curves were so abrupt that the striating and polishing must have resulted from the action of streams of glacial mud and gravel being under stress and driven with unusual force through the confined and winding channel.

This seems to be the point farthest south in the state where such grooves and striae have been noted. At La Platte light grooves and striae have been reported in the Carboniferous limestone. In the Dakota Cretaceous near South Bend, Mr. Charles N. Gould has observed parallel grooves which may be glacial, or as he thinks more likely artificial, being made by the Indians in former times when sharpening implements in the sandy rock of this formation. In the spring a considerable area at Weeping Water will be stripped of the overlying drift and loess, at which time it can be examined to much greater advantage than now.

Erwin Hinckley Barbour.

The University of Nebraska.

A NOTICE OF A NEW AREA OF DEVONIAN ROCKS IN WISCONSIN

There is an outcrop of Devonian rock on the shore of Lake Michigan in this state, ten miles north of Port Washington and about a mile southeast of the little village of Lake Church, which has hitherto escaped the notice of geologists. The discovery of this exposure by the writer in the summer of 1896 was somewhat of a surprise as all the nearest outcrops of rock, to the north, south, and west, belong to the Niagara formation. In the neighborhood of Lake Church the heavy drift deposits, which form high bluffs on the very edge of the lake at Milwaukee and at Port Washington, recede quite a distance from the shore and take the form of a series of rolling ridges which increase in height towards the west. Between the lowest of these ridges and the lake there stretches a sort of terrace, elevated only five or six feet above the lake level at its eastern margin and rising very gradually as it recedes from the shore. The rock in question forms the floor of this terrace and crops out in various places in the neighborhood upon the beach and under the water. It is also uncovered in the bed of a little watercourse which traverses the terrace. The strata are nearly level but probably dip slightly towards the east. The rock is an impure limestone, somewhat earthy in composition and somewhat granular or sandy to the touch. An inconsiderable excavation has been made in it by the owners, disclosing a thickness of about six feet of Devonian strata, beneath which is a transition layer of bluish shaly rock, resting on a very hard, white, crystalline limestone which probably belongs to the Niagara.

About sixty species of fossils have been obtained from the upper layers, all of which, with the exception of a single fragmentary dental plate of Rhynchodus, are in the form of casts and impressions, a fact which renders their determination a matter of some difficulty. The fauna comprises about twenty-four

species of brachiopods, twelve or thirteen of gastropods, nine corals and half a dozen pelecypods. *Orthoceras*, *Rhynchodus*, and *Proëtus* are each represented by a single species; there are scattered crinoid joints and a few other species whose generic relations, even, have not yet been satisfactorily determined.

Among the most abundant species are: *Chonetes scitulus* Hall, *Stropheodonata nacrea* Hall, *Atrypa reticularis* L. and a species of *Spirifer* with a marked depression in the fold of the brachial and a remarkably broad and strongly impressed muscular area in the pedicle valve. Two or three other species, both of *Spirifer* and of *Stropheodonta*, are apparently represented. *Stropheodonta demissa* Conrad is probably one of the latter; another is a strongly arcuate form, with a thick shell and an almost smooth surface. Among other species which have been identified are *Cyrtina hamiltonensis* Hall (rare), *Orthis impressa* Hall (a single specimen), *Atrypa spinosa* Hall, *Productella spinulicosta* Hall, and *Conocardium cuneus* Conrad (the three last fairly common). There is also a species of *Athyris;* one of *Meristella;* a *Cyclonema*, near *C. multilira* Hall; two species of *Loxonema* of ordinary form; a tapering *Turritella*-shaped shell, with both revolving and transverse striae, resembling but not identical with certain forms occurring in the Devonian of Manitoba and referred by Whiteaves to the genus *Loxonema;* a *Murchisonia*, near *M. turbinata* Schlotheim; a *Trochonema*-like shell with strongly angular and nodose revolving ridges; a *Bellerophon*, near *B. pelops* Hall or *B. newberryi* Meek; a *Paracyclas* and a *Mytilarca.* Among corals are a species of *Streptelasma;* one of *Zaphrentis;* one of *Acervularia* and another of an allied genus; and a species of *Favosites.*

The rock in which this fauna has been discovered is thought to constitute good material for road-making. A more extensive development of the quarry, which it is hoped will take place before long, will furnish opportunities for more satisfactory investigation of the fossils.

CHARLES E. MONROE.

MILWAUKEE, WIS.,
April 25, 1900.

KINDERHOOK STRATIGRAPHY

At frequent intervals during the past decade, there have appeared notes on certain beds, occurring in different parts of the Mississippi valley, which have passed under the general name of Kinderhook. For the most part these notes have dealt with local phenomena. In the present connection attention is called briefly to some problems of broader significance.

Along the upper Mississippi River the formations immediately underlying the great Burlington limestones are exposed chiefly in two localities. One is at Burlington, Iowa, and the other at Louisiana and Hannibal, Missouri, and at Kinderhook, Illinois, which is only a few miles from the last named place. Between the two localities the distance is 125 miles. In this distance a shallow syncline carries down the Kinderhook beds 200 feet below the level of the stream.

The early investigations of this Burlington-Louisiana section were carried on simultaneously at the two ends, but by different persons. When the time came to parallel in detail the vertical sections at the extremes difficulties arose. The various beds could not be traced from one point to another because, for most of the distance, the strata were not open to inspection. The method of correlation by visible continuity was inapplicable. Comparison by similar lithologic sequence was likewise unsatisfactory, because the sections were so very different, and it was impossible to tell when or in what manner the changes took place.

When the fossils of the two localities were compared, the results were singularly futile, so far as throwing light upon the problem of exact stratigraphic equivalency. The organic forms were unequally distributed. A large part of both sections had yielded no fossil remains at all. In the northern locality the known animal remains had been found chiefly at the very top

of the section; in the southern, at the very bottom. As to the exact horizons of their occurrence the literature usually gave small clew. With most of the forms no comparison was possible, for the facies of the two faunas were of very different types. After an elapse of 30 years the question of the geological age of the various beds presented itself as formidably as when first these rocks were brought into notice.

Of late years a number of deep wells have been drilled along the upper Mississippi River. These have enabled various geological sections exposed at points far removed from one another to be connected with a degree of confidence never before attained. In the Louisiana-Burlington cross-section, wells at Hannibal, La Grange, Keokuk, Burlington and other points have disclosed important features. These purely stratigraphical features are of particular interest at the present time because of their bearing upon the lack of geological integrity of the typical Kinderhook.

On all of the problems mentioned, the data derived from the deep-well sections have an important bearing. Furthermore, it is pointed out just along what lines critical evidence is to be sought.

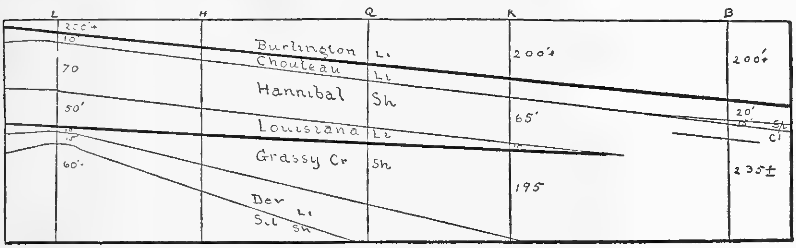
A few years ago the geological sections at the type localities of the several parts making up the Mississippian series of the Carboniferous, were personally studied in order to find out from first hands just what each really meant.[1] Among these sections were those found in the vicinity of Kinderhook, Illinois, which were the basis of what had been long considered the lowermost member of the Carboniferous system, and had been widely known as the Kinderhook formation. Hannibal and Louisiana, Missouri, which are not far away, exhibited the same rocks even to better advantage, and therefore were regarded in all respects as essentially typical.

As is well known, the typical Kinderhook has been regarded as consisting of three members: A basal Louisiana limestone, a median Hannibal shale, and a capping Chouteau limestone.

[1] Principal Mississippian Section; Bull. Geol. Soc. America, Vol. III, pp. 283–300, 1892.

These three members retain their lithological characteristics over broad areas, the extent of which is surprising. The distances of continuity are so great that ordinarily doubt would be cast upon this assumption were it not for the fact that all observations are easily checked by the overlying Burlington limestone. While the lithological features of the several parts of the Kinderhook are so persistent, the faunas contained appear to be remarkably local in nature. The existence of a large number of restricted faunas, in place of a general one is probably the chief cause for past failures to correlate, by the biotic method, the various sections of the Kinderhook.

The stratigraphical relationships of the Burlington and Louisiana sections at last appear to be indicated by the aid of the deep wells drilled between the two points. These relationships are best expressed by the following diagrammatic cross-section, in which, however, while drawn to a scale, no allowance is made



for the synclinal attitude of the strata. What has been regarded as the typical Kinderhook formation is included between the heavy lines.

Immediately beneath the Louisiana limestone, the basal member of the Kinderhook at Louisiana and vicinity, is the Black shale of the Devonian, according to Meek and Worthen.[1] In the neighborhood of Louisiana it has been called the Grassy Creek shale.[2] While at the town itself it only has a thickness of about six feet, and thins out completely to the south, it is 30 feet thick on Grassy Creek, a few miles to the west. Northward,

[1] American Jour. Sci. (II), Vol. XXXII, p. 228, 1861.

[2] Proc. Iowa Acad. Sci., Vol. V, p. 63, 1898.

this shale bed grows rapidly in thickness, until at Keokuk it reaches 195 feet.

The Louisiana limestone, which is over 50 feet thick at the type locality, appears to get thinner northward. At Keokuk it is only 10 feet in thickness, and seemingly fails altogether before Burlington is reached. Its southern extension is not known. It is not believed to be as extensive as Missouri geologists have generally supposed. The Lithographic limestone of southwestern Missouri is not thought to be the same. The apparent fading out towards the north is not an unusual phenomenon among the limestones of the region. Similar cases are known in the Missourian series, or Upper Coal Measures, farther west.[1]

At Louisiana and Hannibal, the shales bearing the latter name have a thickness of about 70 feet. This thickness is maintained northward at least as far as Keokuk, as deep wells show. Beyond this point at Burlington a very similar shale, appears in the base of the river bluffs, having a thickness, including the upper sandy portion (Chonopectus sandstone of Weller[2]), of 85 feet, above the river level. Shale is known to extend downward at least 150 feet more, making a total measurement, from the top of the Chonopectus sandstone, of 235 feet.

The question has arisen as to how much of the Burlington section[3] can be regarded as representing the Hannibal shale. On fancied lithologic grounds solely it was early suggested by Worthen[4] and White[5] that the earthy fragmentary limestone, 15 to 18 feet thick, overlying the lower "yellow sandstone" (the Chonopectus bed) was the northern extention of the lithographic (Louisiana) limestone of Missouri. This view has been recently again alluded to by Weller.[6] If this were the case all

[1] Proc. Iowa Acad. Sci., Vol. VII, 1900.

[2] Trans. Acad. Sci., St.Louis, Vol. X, p. 57, 1900.

[3] Full detailed descriptions of the various sections here referred to will be found in the lately issued volumes of the Iowa and Missouri geological surveys.

[4] Geology Iowa, Vol. I, p. 206, 1858.

[5] Boston Jour. Nat. Hist., Vol. VII, p. 212, 1860.

[6] Trans. Acad. Sci., St. Louis, Vol. X, p. 123 1900.

of the Burlington section below the top of the Chonopectus sandstone would be beneath the horizon of the Louisiana limestone.[1]

In the recent Iowa[2] and Missouri[3] reports the basal shale as exposed above river level at Burlington was considered as about the equivalent of the Hannibal shale. At the same time it was surmised that this part of the section at Burlington probably rested directly upon certain shales found farther north, and which were commonly regarded as belonging to the Devonian. This, however, was merely a working hypothesis; and opportunity did not present itself to carry out very far the necessary field investigation to either prove or disprove it.

On this supposition the 235 feet of shale, of which about one third is above the river level at Burlington, would represent not only the Hannibal shale, but in its lower unexposed part, a so-called Devonian shale as well. The recent discovery of a rich fauna[4] considered as composed of typical Devonian types gives strength to this idea. Still later Weller[5] gives expression to something of the same conception when he states regarding the occurrence of the Hannibal shales in Iowa, that it is "probable that the section at Burlington is equivalent, or more than equivalent, to the whole of the section as known in Missouri." If we take into consideration the 150 feet of shales below water level the stratigraphic evidence now presented goes far towards proving the statement.

The deep-well sections give no indication that the Hannibal shales, as they are known at the type locality, change materially either stratigraphically or lithologically from Louisiana to Keokuk. There is yet no reason whatever for imagining that they should abruptly thin out entirely between Keokuk and Burlington.

[1] Iowa Geol. Sur., Vol. X, p. 79, 1900.

[2] Iowa Geol. Surv., Vol. I, p. 55, 1893.

[3] Missouri Geol. Surv., Vol. IV, p. 56, 1894.

[4] Proc. Iowa Acad. Sci., Vol. IV, p. 39. 1897.

[5] Trans. Acad. Sci., St. Louis, Vol. X, p. 123, 1900.

One the other hand, all evidence goes to show that the Louisiana limestone gradually becomes thinner as the distance increases from the type locality northward, until at Keokuk it is less than one fifth of its original thickness. Everything indicates that it has faded out completely long before the city of Burlington is reached. If the Hannibal shales have retained anything of their normal thickness, as they have in the long distance from Louisiana to Keokuk, the horizon of the Louisiana limestone would be expected to be not far above the river level at Burlington. No bed at or near this horizon has been found that would correspond in lithological or any other of the characters of the Louisiana formation. The only layer of the whole Burlington section below the base of the Burlington limestone, that at all resembles the Louisiana is the Productal limestone (No. 3 of Keyes, No. 4 of Weller), with a coralline zone at the base (No. 3 of Weller), and overlying the Chonopectus sandstone. The lithologial characters of the two are only remotedly related. There are strong stratigraphic reasons, however, for connecting this stratum, as well as those above it, up to the Burlington limestone, with the Kinderhook limestones still farther north at LeGrand, in Marshall county, Iowa. Still other grounds exist for believing the Productal zone at Burlington to be the attenuated margin of LeGrand beds.[1]

All the stratigraphic evidence, as disclosed by the Mississippi River cross-section, the deep wells along the course, and the general geological features of the region appear to indicate, beyond much doubt, that the Louisiana limestone actually does become attenuated northward from the type locality, and that the underlying Grassy Creek shales and the overlying Hannibal shales merge north of Keokuk. If this be the correct interpretation, the section at Burlington, below the top of the Chonopectus sandstone, including over 100 feet of shales beneath the river level, represents considerably more than the Hannibal shales of Missouri.

[1] There is, therefore, apparently little possibility of the Productal limestone representing anything other than the Chouteau beds as exposed farther south.

The Chouteau limestone, which finds its typical development in central Missouri, appears to be well represented, in the northeastern part of the state where the typical Kinderhook is shown, by 10 feet or more of massive earthy limestone, that is fine grained and contains comparatively few fossils. It is sufficiently distinctive in lithological characters to be readily recognizable in deep-well drillings. At Keokuk, it is over 20 feet thick, and at Burlington, if we consider the interval between the Chonopectus sandstone and the Burlington limestone as representing it, about 30 feet thick. In central Iowa it is believed to be represented by the LeGrand limestone, and is over 100 feet thick, there being about the same development as in central Missouri.

The lithologic features at Burlington, while differing from those farther south and at the type locality in central Missouri, correspond very closely with the characters presented northward. At Burlington, also, it is still chiefly limestone. Here it consists of a thin basal coralline zone, the Productal limestone, the Spirifer sandstone, the Gyroceras oolite and the brown Rhodocrinus limestone. These, however, are local collectors' names, and it is not known how far these distinctions should be really recognized.

Independent of the purely stratigraphical characters of the Kinderhook, as expôsed along the Mississippi River, there are certain faunal features of the formation that are not without interest. Until now, all correlations of the Kinderhook beds have had to be inferred from imperfect fossil data. Moreover, the information has been so inexact for present requirements, that the fossils have to be studied largely anew in order to find out in just what layers the various forms occur. Only in this way can useful and exact comparisons of the faunas be made.

Already Weller has begun, along the lines indicated, a series of "Kinderhook Faunal Studies." Judging from the two installments already issued it is expected that there will soon be available much of the long desired information concerning the exact stratigraphic range of the fossils, and the relationships of the various biotic groups.

CHARLES R. KEYES.

ON THE PROBABLE OCCURRENCE OF A LARGE AREA OF NEPHELINE-BEARING ROCKS ON THE NORTHEAST COAST OF LAKE SUPERIOR

IN a recent paper in this JOURNAL,[1] Dr. Coleman has described, under the name of *Heronite*, an interesting analcite-bearing rock from near Heron Bay, on the northeast shore of Lake Superior, and states that although the occurrence of a dike rock of this composition would indicate the presence of nepheline syenite in the vicinity, no area of this rock had as yet been discovered in that district. Many years ago, while looking over some of the rock collections in the museum of the Canadian Geological Survey, at Ottawa, my attention was attracted by two specimens of a rather coarse-grained, red rock from Peninsula Harbor, Lake Superior, on account of the fact that their appearance suggested that they might belong to the class of nepheline syenites. Sections were made and examined at the time, but no nepheline was found, and the investigation was not carried further owing to lack of material and absence of information as to the exact mode of occurrence of the rock in question.

In connection with Dr. Coleman's paper, however, it may be well at this time to present a few notes concerning these rocks, as they indicate that the district in question affords a field of much interest for petrographical study.

The first of the rocks in question was collected by Dr. Selwyn in 1882, and is labeled "Peninsula Harbor," while the second was collected by Mr. Peter McKellar in 1870, and is labeled "Mount Point, S.E. side, Peninsula Harbor." They both come, therefore, from the same neighborhood, and probably from the same mass. Unfortunately, the specimens cannot at present be found, so that it is necessary to base the descriptions on the four thin sections in my collection.

[1] JOUR. GEOL., Vol. VII, No. 5.

The first of these rocks belongs to the class of the augite-syenites, but is of a peculiar type. The augite is represented by two varieties which pass into one another. One is a purplish-brown augite, which frequently constitutes the inner portion of large individuals, and shades away into an outer border of green augite of the second variety. This green augite also occurs in separate individuals. Both varieties have high extinction angles, and the green variety is probably an aegerine-augite. In addition to the augite, a small amount of deep bluish-green and highly pleochroic hornblende is present. The single section of this rock also contains a considerable amount of a mineral which has the high index of refraction and high double refraction of olivine, and which is destroyed by acid with gelatinization.

The feldspars, which with the augites make up most of the rock, consist in part of orthoclase and in part of microperthite, and possibly anorthoclase, and usually possess a zonal structure, an outer border or rim of microperthite often surrounding an individual of orthoclase nearly free from intergrowths. Small quantities of pyrite and magnetite are also present, as also of a deep brown, almost opaque, non-metallic mineral, which is unattacked, even by prolonged treatment, with concentrated hydrochloric acid, and which is probably one of the rarer rock-making minerals.

The structure of the rock is remarkable, and entirely different from that of the ordinary augite-syenites. The feldspars are idiomorphic, and impress their form on the dark constituents, with the exception of the olivine. These latter occupy the interstitial spaces, and are penetrated by the feldspar laths in a manner suggestive of an ophitic structure. The character of the augite and hornblende, as well as the abundance of the feldspar, suggest a magma rich in alkalis.

The second specimen strongly resembles the first, but in it the hornblende replaces the augite, and is present in large amount. This hornblende is so intensely colored that in many cases it is nearly or quite opaque, but when transparent has a deep

bluish-green color and a marked pleochroism. It has a small axial angle, and resembles in general character the variety rich in ferrous iron and alkalis described from the nepheline syenites of Dungannon, Ontario, under the name of *Hastingsite*.

The feldspars resemble those of the other specimen, but there is proportionally more microperthite and a considerable amount of an acid plagioclase. Fluor spar is also present, in not inconsiderable amount, in the form of large, colorless grains.

The structure is the same as that of the former specimen, the feldspars being idiomorphic, and the dark constituents occupying the spaces between the feldspar laths.

The specimens, therefore, while not actually containing any nepheline, have the character of certain differentiation products of alkali-rich magmas, which are found associated with nepheline syenites and other nepheline-bearing rocks in other parts of the world.

In the Report of the Geological Survey of Canada for 1846-7, Sir William Logan, after describing certain "traps" of this same district, refers to what is apparently the same occurrence, as follows:

"The rock above and below is composed of brownish feldspar and black hornblende . . . . it is large-grained, and the general mass of the country constituting the Old Pic Point and Island appears to be composed of it. Fluor spar occurs as a disseminated mineral in some of the beds. Judging from fragments on the shore, there are some beds composed of white feldspar and occasional groups of orange red grains of elaeolite, the whole studded with brilliant black crystals of hornblende, forming a very beautiful rock. The general mass of these volcanic overflows weathers to a red, and from a distance may be readily mistaken for the gneiss which underlies the chloritic shales."

Although the rocks in question are here classed as belonging to the traps of the district, in the Geology of Canada published by the Geological Survey of Canada in 1863, they are, in a reproduction of the passage quoted above, referred to simply

as "igneous rocks" and nothing is said about their supposed volcanic affinities. In the same publication also, p. 467, the occurrence is referred to as follows:

"On the main shore of Lake Superior, nearly north of the western extremity of Pic Island, is a mass of syenitic rock, composed of red feldspar and hornblende, with zircons which resemble the zircon syenite of Norway." As is well known, this latter rock is an augite-syenite, which in Norway is intimately related to nepheline-syenite.

As all the localities mentioned in this note are near one another on the same stretch of coast, and in the vicinity of Heron Bay, it seems certain that there is in this district a large intrusion of an alkali-rich magma, differentiated into various rock facies, among which there are some containing nepheline and some free from that mineral, and that Dr. Coleman's Heronite is connected with the intrusion in question.

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A NOTE ON THE LAST STAGE OF THE ICE AGE IN CENTRAL SCANDINAVIA

In the Dovre region which lies to the north of Christiania the main divide runs in an east-westerly direction. On the mountain plateaus of this region the parent rock of much of the drift is found on the southern side of the divide; consequently the ice had its movement upstream, at least during part of the ice age.

Fig. 1.—The Dovre region in Norway. The arrows mark the movement of the ice. The shaded part is the last remnant of the great ice according to Dr. Andre M. Hansen.

Dr. Andre M. Hansen has given a reasonable explanation of this fact which may be illustrated by the following diagram, Fig. 2.

The country is steeper on the north side of the divide (*a n*) than on the south side (*a s*). The contour of the ice-cover, on the other hand, formed a rather regular curve, and the movement in it took place from the thickest and highest part (*b*) outward to both sides. Consequently on the stretch (*c a*) the movement was against the slope of the surface as indicated by the largest arrow of the diagram.

Now let us leave for a moment this question of the ice movement and turn to another phenomenon. In the upper parts of the valleys to the south of the divide, strand-lines occur of the same kind as the much discussed "parallel roads"

of the Scottish Highlands. The explanation is the same in Norway as in Scotland; they are the beaches of lakes which were dammed in by ice during the late glacial time. Dr. Hansen has tried to give an elaborate account of the manner in which this came about. He thinks that the ice melted latest where the thickness was greatest, and that the last remnants came to lie as a narrow strip of ice, a sort of "ice sausage," on the slope of the south of the divide and somewhat parallel to it (see Fig. 1). On the diagram the shaded part shows the ice in the last stage, and the lakes were dammed in between it and the divide. The readers of this JOURNAL may remember that this

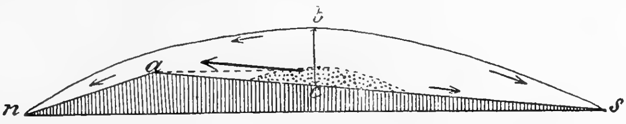


FIG. 2.

explanation was hinted at in a paper by Dr. Hansen, entitled "Glacial Succession in Norway," Vol. II, 1894, p. 137, conclusions, by the way, to which most Norwegian geologists assent only to a limited extent.

By his explanation Dr. Hansen has made urgent the question at what place the last remnants of the inland ice were located. Mr. Schiötz, professor of physics at the University of Christiania, has criticised Mr. Hansen's views from the physical standpoint in a paper entitled "How will the ice divide act during the melting of the inland ice?" printed (in Norwegian) in *Nyt Magazin for Naturvidenskaberne*, Vol. 34, Chr., 1895, pp. 102–111. He demonstrates that any "ice sausage" on the slope below the divide can come into existence only in the case that the melting takes place so suddenly and quickly that the snow line during the period of melting is at a greater height than the crest of the country. If the snow line rises gradually as the temperature rises, the diminishing glaciers will concentrate at the divide. He thinks this the most probable case, and points to the great local glaciers which undoubtedly have descended from the

divide, and to the fact that small local glaciers still exist in the region described. If Mr. Hansen is right, the snow line was first very much elevated, then descended below its present limit, and more recently has ascended again to produce the present conditions.

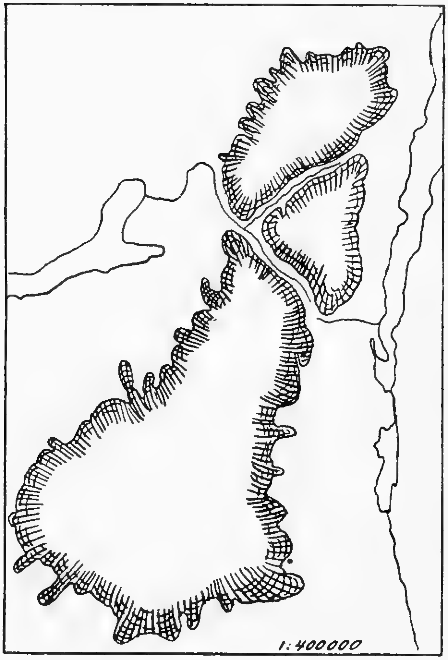


FIG. 3.—The Folgefonn glacier-field.

It seems to the present writer that a study of the now existing Scandinavian glaciers makes another explanation of the ice-dammed lakes more probable than that set forth by Dr. Hansen. It may be remembered that the region in question is to be regarded as a high plateau intersected by valleys. Our chief existing glaciers are also found in country of the same kind, and in accordance therewith they present themselves as gently-domed or shield-like snow-fields, intersected by valleys free of snow. This has long been known of the two great snow-fields of southern Norway, "The Folgefonn" and "The Justedalsbrae." The Folgefonn, for instance, is dissected by valleys into three parts, as seen on the accompanying map. In size the Folgefonn is the second among the Scandinavian glaciers. The greatest is the Justedalsbrae. Next to this comes "The Svartisen" (Svart = swarthy, blackish; isen = ice) situated under the polar circle. Even on our latest maps this glacier has been delineated as an unbroken elliptical snow-field with its greatest dimensions from south to north, although Mr. Rekstad of the Norwegian Geological Survey had shown in 1891 that the snow-field is divided

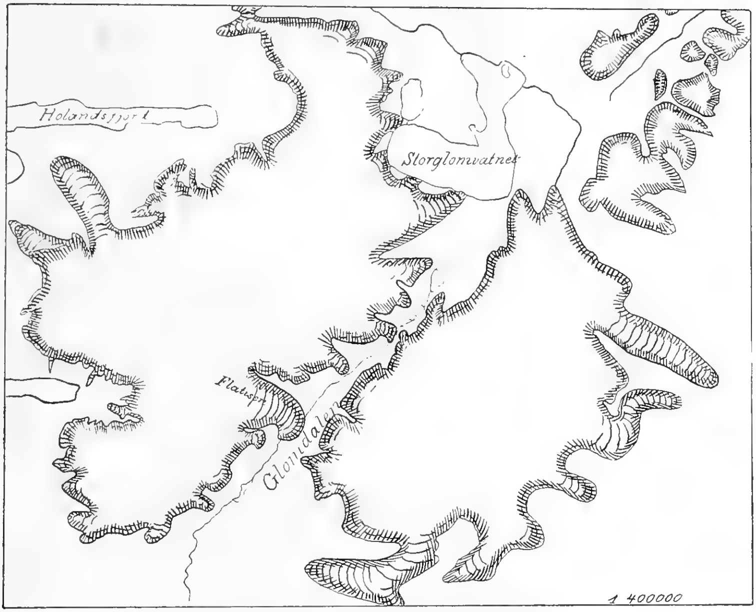


FIG. 4.—The Glacier of Svartisen.

FIG. 5.—Glaciers descending from the Svartisen to the Glomdal valley.

into two by a desert valley, the Glomdal (dal = valley). He was the first Norwegian known to have entered the inner part of that valley formerly known only to a few Laps, an incident which indicates that geographical discoveries may yet be made within Europe itself. He has described and photographed the principal

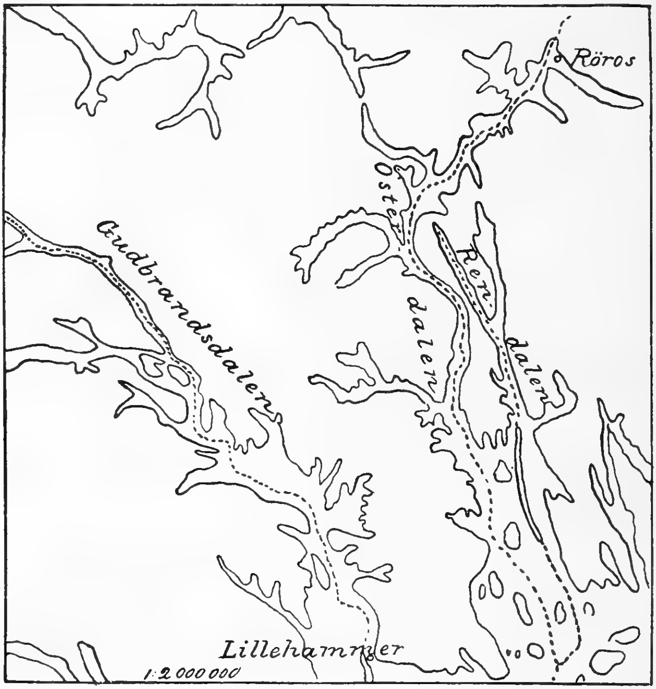


FIG. 6.—The region in the vicinity of the main Scandinavian divide to the north of Christiania. The line of 100 meters above the sea is shown.

glaciers descending into the Glomdal. The greatest is presented herewith. The Norwegian Topographical Survey has of late made a more detailed map of the region. With the aid of their material, which has not as yet been published, the present sketch map was made, Fig. 4.

If we now turn to the region of the old ice-dammed lakes, we find a country well fitted for similar extensive fields of ice and snow, with empty valleys between. The map (Fig. 6)

shows how the line of 100 meters encompasses narrow branching valleys. We may easily imagine that during a certain stage of the melting this line was the snow line and determined the extension of the snow-fields. Some glacier descending from one of the greater side-valleys may have stopped back the water of the main valley and formed a lake. Mr. Rekstad says that the river that issues from the Glomdal valley sometimes

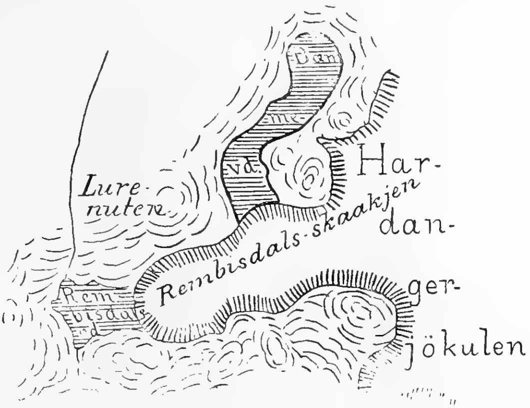


FIG. 7.—The Daemmevand (dammed lake) in Hardanger.

rises enormously, and that the flood is probably due to the fact that the water is temporarily obstructed by the chief glacier that intrudes upon the valley. Norway has its Märjelen See corresponding to the famous Swiss lake as is well known among geologists through Lyell's Principles. The Norwegian glacier-dammed lake is the Daemmevand (the blocked-up lake) in the province of Hardanger, in the high region to the east of the town of Bergen. From an extensive snow-field, the "Hardanger jökul" (jökul = glacier) descends to a lake. On its way it blocks up the "Daemmevand." This lake has of late attracted some attention, as the water sometimes breaks through the glacier and causes sudden and destructive floods. To prevent this the government has made a tunnel about 300 meters long

through a spur of the mountain called Turumeten. This tunnel has had the effect desired in preventing the lake rising above a fixed level. Mr. A. Holmsen, who had the supervision of the work, has had the kindness to communicate a sketch-map (Fig. 7) of the surroundings of the lake, and a photograph of the blockading glacier with a part of the lake in the foreground.

FIG. 8.—The ice barrier in front of the lake Daemme, sketched from a photograph.

From a dam like this we may mentally reconstruct a barrier capable of accounting for the lakes dammed back in olden time in the Dovre region.

There are two English accounts of this lake, viz., that of Mockler-Ferrymann ("The Daemmevand of Rembesdals Glacier Lake, *Geogr. Jour.*, IV, Dec. 1894, London, pp. 524–528) and that of Munro ("On a Remarkable Glacier Lake formed by a branch of the Hardanger-Jökul, near Eidjford, Norway, *Proc. of the Roy. Soc. of Edinburgh, Session 1892–3*, Vol. XX, pp. 53–82). The two Norwegian scientists, Bing and Öyen have also made reports on the lake.

HANS REUSCH.

STUDIES FOR STUDENTS

THE PROPERTIES OF BUILDING STONES AND METHODS OF DETERMINING THEIR VALUE. II.

In selecting a stone for building or other economic purposes, one should be familiar with the

I. Color.

II. Composition, { Mineralogical, Chemical.

III. Strength, { Crushing, Transverse.

IV. Hardness.

V. Elasticity.

VI. Porosity (including fissile planes).

VII. Specific gravity.

VIII. Weight per cubic foot.

IX. Effect of temperature changes.

(*a*) Freezing and thawing of interstitial water.

(*b*) Effect of extreme heat.

X. Effect of gases, { Carbonic, Sulphurous.

XI. Quarry conditions.

There are three important methods of obtaining these facts: (1) observations at the quarry and adjacent natural exposures; (2) examination of buildings, monuments, or other constructions built out of the stone; (3) laboratory examination. If a geologist were obliged to choose between the three, he would probably consider the first method most satisfactory. The architect and builder, on the other hand, would undoubtedly choose to examine buildings already constructed out of the stone. However, the value of opinions based solely upon quarry observations or the inspection of buildings depend largely upon the

judgment and experience of the observer. They lack a definiteness and certainty which can only be supplied by the laboratory tests. No one of these should be considered sufficient in itself, but each should be used in conjunction with the other two.

QUARRY OBSERVATIONS

Several important conclusions may result from quarry observations which cannot be reached through an examination of buildings or selected samples in the laboratory. Chief among these may be mentioned: (1) the probable injury to the stone from quarrying, handling, and dressing; (2) the capacity of the quarry to furnish as needed the required quantity of stone of the desired quality; (3) the uniformity in color and mineralogical composition, and the apparent uniformity in strength, hardness, elasticity, and porosity.

Stone is often more or less injured through improper methods of quarrying and dressing or careless handling, as explained in the previous paper.[1] One can become familiar with the methods employed in quarrying the stone only by visiting the quarry where the work is being carried on.

The knowledge that a quarry has the capacity to furnish as needed the required quantity of stone of the desired quality is an important matter. A quarry is sometimes poorly equipped with machinery; men may be scarce; orders for stone may be plentiful; and as a consequence inferior stone is placed upon the market for the better grade. The situation of the quarry in these respects can be best determined by an examination of the quarry and its equipment.

The uniformity in the color of the stone can be quickly determined by an examination of the quarry. If the stone differs in color at different horizons, or in different parts of the quarry, precautions can be taken in the specifications to insure the receipt of stone of a uniform color by designating that it be taken from a definite part of the quarry.

[1] JOUR. GEOL., Vol. III, No. 2, pp. 181–184.

Stone from different parts of the same quarry may differ widely in mineralogical composition, strength, hardness, elasticity, and porosity. Differences in these respects, when of importance, may be detected through quarry observations. However, in order to ascertain these differences, one needs to be thoroughly familiar with the conditions controlling these properties. Differences in mineralogical composition may be recognized by one who is familiar with the common rock-forming minerals.

Differences in the strength of stone result from differences in mineralogical composition, and in size, shape, and manner of contact of the individual grains, all of which can be made out by an experienced observer.

Not only can an experienced person detect differences in the qualities of stone from various parts of the same quarry, but he can also make comparisons with stone from other known localities.

At the quarry the unweathered stone can be compared with that of the natural outcrop which has been exposed to the atmosphere for many years. Comparisons based upon such observations furnish very fair estimates of the permanence of color and the degree of hardness, strength, and durability of the stone. Such estimates, however, must necessarily be very general, because of the uncertain length of time that the weathered stone has been exposed to the atmosphere. It may have been uncovered for centuries, or perhaps for only a few years.

In the outcrop the stone may be found bleached, stained with brown, or discolored with white efflorescent patches. Bleaching ordinarily proceeds very slowly and extends to no great depth, and is therefore of little importance. Brown staining usually indicates the presence of iron, and the white efflorescent patches give evidence of magnesium or calcium salts.

In glaciated regions the hardness of a rock is frequently estimated by the depth and extent to which the surface has been grooved or striated. However, this is a very uncertain evidence of hardness, being controlled largely by the condition of the

glaciers as they passed over the region in question, and the length of time that the surfaces have been exposed to the atmosphere since glaciation.

The durability of a stone is occasionally estimated from the depth to which disintegration has extended. The extent of disintegration, however, has the uncertain time element in it, which may vitiate the conclusions.

Observations on stone in the natural exposure, where disintegration has not gone too far, reveal inequalities in hardness caused by concretions, nodules, pebbles, clay seams or pockets, and fossils. Weathering also emphasizes sedimentary and jointing planes, which are obscure in the freshly quarried rock. It is often contended by quarrymen that joints die out with depth, but this cannot be laid down as a general rule. Some joints are probably superficial, but others certainly penetrate to very considerable depths. The farther the joints extend laterally, the greater is the probability that they will continue to a considerable depth.

A luxuriant growth of lichens on a natural exposure of rock is frequently taken as evidence of durability. Unfortunately this criterion of durability, when taken alone, has little significance. An abundant growth of lichens has often been observed on the surface of sandstone which was inherently soft. Such occurrences simply indicated that a crust had been formed on the exposed surface of the stone.

If one is desirous of obtaining a considerable quantity of stone perfectly uniform in color and texture, it is important that he should visit the quarry to assure himself that the amount of stone of the desired quality is obtainable. It is possible for a quarry to be exhausted of its good stone, and for this reason, an inspection is often a valuable precaution. On the other hand, the stone from a certain quarry, which has a large percentage of number one stone, may have been condemned by the public, because quarrymen and contractor have permitted the use of a few inferior blocks, "for the sake of economy." In order to know when the best stone that a quarry produces is being

received, one should be personally acquainted with the possibilities of the quarry.

OBSERVATIONS ON BUILDINGS

The inspection of constructions of long standing is generally recognized as an important means of estimating the strength and durability of stone. The value of such observations, however, is often overestimated and it frequently happens that strong and durable stone is condemned on account of careless methods of handling and laying.

An estimate of the strength and durability of a stone from its condition in a building should only be måde after one has considered, (1) the age of the building; (2) its size; (3) the climatic or atmospheric conditions; (4) its position; (5) the grade of stone used, and (6) the manner in which the stone was quarried, handled, dressed, and laid.

The age of a building is especially important, it being worse than folly to pass judgment on the stone in a building, unless this is known. A stone may not exhibit any material deterioration during the first twenty-five years in a wall, although the next ten years may show marked decay. As a rule the actual disintegration of the stone in buildings in the United States is comparatively little. Many that are fifty or more years old do not exhibit the first signs of decay. The actual disintegration is frequently so little that the observer must content himself with searching for the beginnings of decay.

The height of a building usually increases the weight of the superstructure and hastens the rate of decay. The atmospheric or climatic conditions, temperate, torrid, frigid, humid, or arid, will affect the permanence of a rock. A stone which would remain unchanged for centuries in an arid region might crumble and decay in a few years in a moist, temperate climate.

The position of a building, in the business or residence part of a city, protected or exposed to the storms and prevailing winds, will affect more or less the life of the stone.

The grade of stone that has been used in the construction of the building under inspection should be known. Nearly every quarry contains more than one grade of stone. However, it is not an uncommon occurrence for the stone from an entire district to be condemned because second or third grade stone has not proved as satisfactory as number one stone from another district. The poorer grades of stone are sometimes used in the fronts of buildings or even carved for the finer parts of the architectural work.

After the stone once becomes a part of a building people do not stop to distinguish different grades, but charge all weaknesses or imperfections against the quarry as a whole. Sometimes an entire area including several quarries suffers in consequence.

It is also important to know the manner in which the stone is quarried, handled, dressed, and laid. Much stone is still being laid on edge, especially in veneer work. Where the bedding planes are prominent and the stone is only of moderate strength, this practice is dangerous. An observer should ascertain if possible whether the flaking and scaling is due to improper methods of laying or to inherent weaknesses in the stone.

Stone used for ornamental and monumental purposes will show deterioration in proportion to its age, position, etc., the same as stone in the walls of buildings. For these reasons, the same care should be exercised in passing judgment on its durability.

The oldest monuments are built out of marble, it being only within a comparatively few years that granite has come into very general use. Nevertheless, some of the important granite monuments, in spite of the comparatively recent data of their erection, are gradually losing their polish and even now have finely pitted surfaces. Monuments that are exposed for years to dust laden winds frequently have their polished surfaces dulled and the lettering obscured. The sides exposed to the direct rays of the sun often deteriorate most rapidly owing to the diurnal expansion and contraction caused by heating and cooling.

The degree of polish which a stone will take and the contrast of the hammered and polished surfaces can be best estimated from the finished work. One should be mindful, however, at all times, in making comparisons, not to allow the elaborateness or excellence of the workmanship to influence the judgment. Dealers sometimes oil the polished surfaces of the monuments, which gives a brilliancy and luster not inherent in the stone itself. For this reason a monument should only be examined after it has been erected for six months or a year.

In the case of stone used for highways and sidewalks much can be learned of its strength and durability by inspecting previously constructed walks and roadways. In these cases, however, a just comparison can only be made when the manner in which the highway or walk has been constructed, the amount of traffic to which it has been subject, the character of the subsoil, the climate conditions, and the data of construction are known. The rapidity and manner in which a stone pavement wears are the important factors to be determined. An examination of pavements built out of the stone will indicate whether it wears unevenly, is slippery, or is easily abraded.

LABORATORY TESTS

One who is fully acquainted with the mineralogical and chemical composition, the physical characteristics of a stone, and the climatic and other conditions to which it will be subject when in use, can predict with a remarkable degree of accuracy, without inspecting the quarry or examining buildings of long standing, the results of exposure to the atmosphere. It is not always possible to have a laboratory examination made, and frequently it is unsought for by quarrymen, who often prefer to rely upon their own statements to sell their stone.

The important laboratory tests are included under three general classes, viz., (1) chemical; (2) microscopical; and (3) physical.

CHEMICAL

The chemical analysis is the only exact method of determining the composition of a rock in terms of the elements that compose it. It is also the best method of determining the relative proportions of the mineral constituents. The presence of deleterious constituents, such as ferrous iron, bitumen, etc., and the proportion that they bear to the total mass of the rock may also be determined in this way.

MICROSCOPICAL

Much may be learned of the mineralogical composition and physical characteristics of most rocks by a careful examination of the hand specimen, especially with the aid of a magnifying glass. Many rocks, however, are so fine grained that the mineralogical composition and texture can only be accurately determined by an examination of thin sections under a compound microscope.

It is thought that the microscopical examination is of much greater practical importance and less expensive than the chemical analysis. By use of the microscope and thin sections both the mineralogical composition and texture of a rock can be determined with a high degree of accuracy. The relative abundance of the different minerals and even the chemical composition can be approximately estimated. Minerals that are easily decomposed and liable to cause discoloration can be identified, and the presence of cracks, strains, and gas bubbles can be detected. A single caution should be observed in this connection. Cracks and strains are thought to be frequently due to stresses resulting from cutting and grinding the thin section, on account of which care should be exercised in drawing conclusions therefrom. The size and abundance of the pore spaces can be estimated from the texture, closeness, and manner of contact of the grains. All the characteristics of a rock which contribute to its strength, hardness, elasticity, capacity to resist alternating and extreme temperatures, and immunity from the

effects of carbonated or acidulated waters, can be determined by the microscopic examination of thin sections.

It is thought that the use of the microscope, with an intelligent interpretation of the facts revealed thereby, might eventually render unnecessary the performance of the physical tests and the determination of the chemical composition. However, at the present time, this method is only available to the scientist who can interpret the facts thus observed. The accuracy of his conclusions will depend upon his judgment and experience as a petrographer. With the public it may never supplant the physical tests, because it lacks the quantitative element.

PHYSICAL TESTS

The purpose of the physical tests is to determine by artificial methods the strength of a stone and its capacity to resist the destructive agents encountered in actual use. As stated on a previous page, the signs of decay in buildings, on account of the improper methods of quarrying, handling, dressing, and laying are not always evidence of inherent weakness in the stone. For this reason the physical tests, performed in the laboratory, often provide a more reliable basis on which to estimate strength and durability.

It is a comparatively simple matter to determine the strength and elasticity of a stone, both of which can be measured directly by machinery. It is a more difficult problem, however, to express quantitatively the durability, on account of the impossibility of measuring in a few weeks or months in the laboratory any deterioration that might take place under ordinary climatic conditions. Further than this the conditions in nature change from day to day, both in intensity and kind, and as a rule, there are several instead of one agent of destruction operating at the same time. In order to measure the effect of these agents in the laboratory it is necessary to consider them separately, and on such a grossly exaggerated scale that there will be accomplished in a brief period, what in nature would require many years.

Estimates of the strength and durability of a stone from physical tests are usually based upon the following determinations:

1. *Strength*,
   a. Compressive,
   b. Transverse.
2. *Elasticity, modulus of.*
3. *Hardness—coefficient of wear.*
4. *Specific gravity.*
5. *Porosity.*
6. *Weight per cubic foot.*
7. *Effect of Temperature changes*,
   a. Freezing and thawing of included water,
   b. Effect of extreme heat.
8. *Effect of gases*,
   a. Carbonic acid,
   b. Sulphurous acid.

Attempts have been made to classify these tests under "strength tests" and "durability tests," but the classifications thus made are not logical because some of the tests have a double significance.

STRENGTH

A knowledge of the strength of a stone implies a familiarity with its capacity to withstand both compressive and tensile stresses. For this reason both the crushing strength and modulus of rupture should be determined.

Crushing strength.—Up to within a few years the compressive strength test, by means of which the crushing or ultimate strength is determined, has been used for estimating both the durability and strength of a stone. However, a stone with a low crushing strength may be more durable than one in which the crushing strength is high. For this reason the crushing strength, alone, is insufficient for estimating the durability of a stone. In the absence of other tests the importance of the crushing strength has been frequently overestimated.

At the present time, however, it is argued by some that it is folly to determine the crushing strength, except in cases where the strength of the stone is very doubtful. Nevertheless, I do not believe that it is wise to encourage the abandonment of the crushing strength test.

Architects using stone with which they are not familiar, are glad to avail themselves of all crushing strength data. In fact, the only intelligible method of expressing the strength of a stone to one not thoroughly familiar with the interpretation of the mineralogical composition and texture, is in pounds per square inch.

Other than this the crushing strength determinations have an important scientific bearing upon problems in dynamic geology, and for this reason if no other the test should be continued.

It is not uncommon for a stone to be so situated in a building that it must sustain a heavy load. In very large buildings single columns and blocks are often required to carry huge masses of superstructure. Bridge trusses are often supported on blocks of stone which sustain the combined weight of the superstructure. Before using a stone for any of these purposes it is well to know with a fair degree of accuracy its crushing strength.

The pressure exerted on the stone in the lower courses of a building of ordinary dimensions is not very great. It has been computed that the stone at the base of Washington monument sustains a maximum pressure of 22.658 tons per square foot, or 314.6 pounds per square inch. Most architects require a stone to withstand twenty times the pressure to which it will be subjected in the wall. This factor of safety, however, would only require a crushing strength of 6292 pounds per square inch for stone at the base of the Washington monument. The pressure at the base of the tallest buildings yet constructed in this country can scarcely exceed one half that at the base of this monument, or 157.3 pounds per square inch. With a factor of safety of twenty the stone used in such positions must have a crushing strength of 3146 pounds per square inch. There are very few

building stones in the country that do not have a higher crushing strength. It may happen, however, that owing to an unequal distribution of the load certain stones in the wall or columns, will be called upon to sustain twenty, or even fifty times the natural load, in which case the crushing strength should be much greater. All things considered, however, a crushing strength of 5000 pounds per square inch is considered sufficient for all ordinary building constructions.

The crushing strength of a stone can be obtained quickly and accurately in any laboratory which is provided with appliances for cutting and dressing stone cubes and a testing machine, for determining the compressive strength. The cubes to be tested should measure uniformly $2 \times 2 \times 2$ inches, this being generally conceded to be the standard size. Smaller or larger cubes may be used, but some authors, following the early experiments of General Gilmore, still maintain that the crushing strength per unit of area varies with the size of the cube tested. Believing this, General Gilmore constructed an empirical formula for the purpose of reducing all tests to pounds per square inch on two-inch cubes. However, it has been shown to the satisfaction of most persons, that this formula is neither theoretically nor practically true. It is now believed quite generally that the crushing strength per square inch is the same whether the cubes tested be large or small; cubical or prismatic in shape. Until this question is settled to the satisfaction of all it is best that all tests be made upon two-inch cubes.

The cubes should be very carefully sawed from stone which has not been injured by rough handling or hammer dressing. The faces should be rubbed smooth, and the opposite sides should be made parallel. Before the cubes are placed in the testing machine they should be thoroughly dried and the average area of the bearing faces determined. Thin strips of blotting paper, wood, or lead, are often placed between the steel plates of the machine and the bearing faces of the stone cubes, to assist in distributing the load. It is claimed by some, however, that this has a tendency to lower the crushing strength. The

author believes, that for the sake of uniformity, at least, it would be best to apply the bearing faces directly to the steel plates of the machine, a spherical compression block being used in making the test. Record should be kept of the direction in which the pressure is applied with respect to bedding.

The load at which the cubes are first cracked, the ultimate strength, the perfection of the resulting pyramids, and the explosive manner in which the cubes break should be carefully noted. The crushing strength per square inch is computed by dividing the ultimate strength by the average area of the bearing surfaces in square inches.

Transverse strength.—The transverse strength is measured in terms of the modulus of rupture. This is the force required to break a bar of any material one inch square, when resting on supports one inch apart, the load being applied in the middle. The determination of the modulus of rupture is of far greater importance in masonry construction than would be supposed from the very meager data available. The broken lintels, caps, and sills which are so conspicuous in many of the larger buildings in this country, testify to the need of a more general appreciation of the value of this test. Many building stones that are perfectly suited to withstand the compressive stresses in the body of the wall, have such a low modulus of rupture as to be unfit for use in a position where a high transverse strength is required.

The necessary thickness of a lintel, cap, or sill depends mainly upon the transverse strength of the stone. In order to avoid possible danger from weak stone or unequal stresses, the doors and windows of the heavier buildings are often arched.

For the purpose of obtaining the modulus of rupture, pieces should be prepared by sawing, and should have a cross section of one square inch and a length of from six to eight inches. The sides should be smooth and the opposite faces parallel. The pieces thus prepared should be placed in a testing machine, in which both ends are supported and the pressure applied in the middle. The weight required to break the sample and the

position of the rupture should be carefully recorded. The modulus of rupture is then computed from the following formula:

$$W = \frac{2bd}{3l} R, \text{ from which}$$

$$R = \frac{3l}{2bd} W.$$

W = concentrated load at center in pounds.
b = breadth in inches.
d = depth in inches.
l = length.
R = modulus of rupture in lbs. per sq. in.

Modulus of elasticity.—The modulus of elasticity is synonymous with coefficient of elasticity, and is sometimes defined as the weight that would be required to stretch a rod one square inch in section to double its length. The result is generally expressed in pounds per square inch. It is "valuable in determining the effect of combining masonry and metal, of joining different kinds of masonry, or of joining new masonry to old; in calculating the effect of loading a masonry arch; in proportioning abutments and piers of railroad bridges subject to shock," etc. Baker.)

One method of measuring the modulus of elasticity is by recording the amount of compression which a two-inch cube of stone undergoes for each increment of 500 to 1000 pounds up to the limit of elasticity. From the data thus obtained the modulus of elasticity is computed by use of an empirical formula.

The value of such determinations from a commercial standpoint are somewhat doubtful, owing to the fact they are seldom referred to by architects. The sparcity of the determinations in this country is undoubtedly one reason for their uselessness.

Hardness.—The hardness of a stone may be determined quantitatively by the use of an abrading machine, and the results expressed as the coefficient of wear. The abrasion test is used mainly for determining the wearing qualities of crushed rock for

macadam but it is thought that such tests will prove valuable and important for determining the suitability of stone for steps, sidewalks, and flooring.

The abrading machine that is considered best suited for determining the coefficient of wear is that used by the Wisconsin Geological Survey, and patterned after the machine used by the Massachusetts Highway Commission.[1]

Specific gravity.—The determinations of the specific gravity of building stones that have come under my observation have been based upon two very different conceptions. According to one of these conceptions the specific gravity depends entirely upon the mineralogical composition, and is independent of the porosity of the stone. According to the other conception the pores are considered a part of the stone and the specific gravity is computed for the exterior volume. These two methods give different results for the same stone, and have been designated by Regis Chauvenet as "Specific Gravity Proper" and "Apparent Specific Gravity." Where the porosity of a stone is less than 1 per cent. the two specific gravities are almost the same. But where the porosity is 10 or 25 per cent., they are very different.

In most discussions of building stone tests the principle laid down by Professor J. C. Smock[2] that, the specific gravity of the *particles or mineral species* composing the rock mass, determines that of the stone has been followed.

The practical engineer, however, objects to this method, because he cannot compute the weight of the stone per cubic foot directly by multiplying by 62.5, the weight of an equal volume of water. Several contemporary writers on building stones, however, have unfortunately made the mistake of determining the "specific gravity proper" and then computing the weight per cubic foot by multiplying this directly by 62.5. For

[1] For description of this machine see the Report of the Massachusetts Highway Commission for 1899, pp. 59, 60.

[2] Bulletin of New York State Museum, Vol. II, No. 10, p. 374, PROFESSOR J. C. SMOCK.

example one author gives the following as the results of his experiments on three different stones.[1]

Number	Specific gravity	Weight in lbs. per cubic foot	Per cent. of water absorbed
C 2314	2.6236	163.50	18.07
C 2183	2.6166	163.07	3.62
C 2316	2.5380	158.17	8.71

It will be observed as a result of these experiments that the stone which absorbed 18.07 per cent. of water weighed more than the one that absorbed only 3.62 per cent., although the difference in specific gravity is only .007.

Another author says: "If we find that a stone has a specific gravity of 2.65 . . . . we get its weight by simply multiplying 62.5 by 2.65 which gives us 165.62 . . . ."[2] In this statement reference is made to the "specific gravity proper" and not the "apparent specific gravity." Results obtained in this way would obviously be incorrect. Similar inaccuracies in the determination of the specific gravity and weight per cubic foot, occur in other published reports, but those above quoted suffice as illustrations.

I believe that the specific gravity should be determined on the principle laid down by Professor J. C. Smock[3] and that the "apparent" specific gravity should only be used in computing the weight of the stone per cubic foot. There is no inconsistency in this, in so much as the commercial weight considers only the external volume and does not consider the stone as a geometric solid. At least there should be a recognized uniform method of computing the specific gravity of stone.

The specific gravity proper of a rock can only be obtained by weighing the samples in air, at a definite temperature, after all interstitial water has been expelled; then weighing them,

[1] Bulletin of New York State Museum, Vol. II, No. 10, Table, p. 358, by Francis A. Wilber.

[2] The Building and Decorative Stones of Maryland. Maryland Geological Survey, Vol. II, p. 119, Geo. P. Merrill.

[3] *Ibid.*

completely saturated with water, in water; and finally dividing the weight in air by the difference. These ideal conditions of absolute freedom from interstitial water in the one case, and complete saturation in the other, are difficult to obtain. Nevertheless, if accurate methods are employed and care is exercised in manipulation it is thought that a high degree of accuracy can be attained.

As previously stated, it is advisable to perform all tests on two-inch cubes. In obtaining the specific gravity, the samples should be cleaned by carefully washing, and dried for twenty-four hours in a hot air bath at a temperature of 110° C. The samples should then be weighed and the weights recorded in grams to the second decimal place. The samples should then be transferred to a large bottle or other glass receptacle, corked tightly, and sealed. This bottle should then be transferred to a water bath having a temperature of 100° C. Three glass tubes, one leading to an air pump, another to a manometer, and a third to a basin of boiling water are passed into the bottle through holes in the cork. By means of the air pump, the air in the bottle should be exhausted until the pressure, as indicated by the manometer attachment, is lowered to at least one twelfth of an atmosphere. The pressure should be maintained at this point while distilled water at a temperature of 100° C is drawn into the bottle through the third tube. This tube which conveys the water should be partly rubber and should extend to the bottom of the bottle. A stop cock is used to regulate it. By starting the air pump and operating the stop cock at the same time it is possible to keep the pressure nearly constant and at the same time draw any desired amount of water into the bottle. By this process, the air in the pores is gradually replaced by the water which fills the vessel from below. After the cubes are completely covered with water, they should be allowed to remain in the bottle twenty-four hours maintaining a pressure of one twelfth of an atmosphere.

The saturated samples should then be quickly transferred to a basin of distilled water and removed to the weighing room.

After removing the samples from the basin, the water adhering to the surface should be deftly removed by the use of bibulous paper, the samples transferred to the scale pan, and quickly weighed. Through the transference of the samples from the basin to the scale pan there are two sources of error, one is through the use of bibulous paper, and the other through evaporation. No plan has yet been devised to avoid these sources of error, wherefore the skill and judgment of the operator must be depended upon.

After these weights are recorded the samples should be suspended by a silk thread in distilled water and again weighed. After this weight is recorded the samples should be transferred to a hot air bath and dried at a temperature of 110° C. until the interstitial water has been entirely expelled. The samples are again weighed and the results recorded. From the weights thus obtained the specific gravity is determined by dividing the average of the two dry weights by the difference between the average dry weight and the weight of the cube suspended in water.

The apparent specific gravity can be readily obtained by subtracting the weight of the sample suspended in water from the weight of the sample saturated with water and dividing the average dry weight by this difference.

Porosity and ratio of absorption.—These terms have been used interchangeably as applying to the percentage of the weight of the absorbed water to the average weight of the dry sample. This ratio, however, is not the percentage of actual pore space, but simply the relation between the weight of the rock and the weight of the water absorbed. The term porosity should only be applied to the percentage of actual pore space in the rock while the ratio of absorption should be restricted to the percentage of the weight of the absorbed water to the average weight of the dry sample. The former gives the volume relation and the latter the weight relation. To my knowledge no American writer has computed the actual pore space or porosity of building stones. However, I believe that this determination is more important than the ratio of absorption.

The method of obtaining the porosity which is ordinarily employed is as follows: The sample to be tested is heated at a temperature of 100° C. to drive off the moisture. After cooling, the sample is weighed, and then slowly immersed in distilled water. After bubbles cease to be given off, the sample is removed from the water and the surface quickly dried with bibulous paper, after which the specimen is again weighed. The difference in weight gives the increase due to the absorption of water. This difference divided by the weight of the dry stone is taken as the ratio of absorption or porosity.

Several errors are apparent in this method. The interstitial water is not easily expelled at a temperature of 100° C. To expel the moisture in a moderate length of time, the stone should be dried at a temperature of 110° C. Further, the samples cannot be completely saturated "by immersing in distilled water until bubbles cease to be given off." Finally the method of computation gives the ratio of absorption and not the percentage of actual pore space or porosity.

The porosity of a stone should be obtained in the following manner, using the determinations made in performing the specific gravity tests. The average weight of the dry sample should be subtracted from the weight of the saturated sample, to obtain the weight of the water absorbed. This, multiplied by the specific gravity of the stone, will give the weight of a quantity of stone equal in volume to the pore space and of the same specific gravity as the stone tested. This weight divided by the weight of the dry stone will be the porosity or actual percentage of pore space.

The ratio of absorption can be obtained by dividing the weight of the absorbed water by the weight of the dry stone.

In another part of this paper I have shown that neither the porosity or ratio of absorption, alone, indicates the value of a stone for building purposes. It was pointed out that the size of the pores is by far the more important consideration. This can be estimated roughly, when the size and shape of the grains and percentage of pore space are known. If only the ratio of

absorption is available the calculations of the size of the pores are liable to be less accurate.

For scientific purposes, other than determining the quality of a stone for building, the porosity, and not the ratio of absorption is the factor sought after. The porosity test will result in a higher percentage than the ratio of absorption, and may therefore meet with disfavor among quarrymen. However, when it becomes known that the value of a stone cannot be estimated from its porosity except when the size of the pore spaces is known, objections will cease. In all cases it is thought that the porosity should be determined in preference to the ratio of absorption.

Weight per cubic foot of stone.—The weight of stone when it is first quarried, depends upon its specific gravity, the amount of pore space, and the water content. For a given stone, the only fluctuating element is the water content. In the more porous rocks this will vary at different seasons of the year and will depend upon the thoroughness with which the rock has been seasoned. Any determination of the weight per cubic foot of a stone which includes an indefinite quantity of interstitial water is unscientific and unsatisfactory. Determinations thus made depend upon a number of conditions, changes in any one of which will give a different result. The only constant weight is that of the dry stone.

The commercial weight of a stone may be obtained in two ways. First, by weighing directly a known volume of the stone which has been thoroughly dried at a temperature of 110° C.; second, by computation from the data obtained in determining the porosity. By the second method, the weight of a cubic foot of stone can be obtained by multiplying the weight of a cubic foot of water by the specific gravity proper of the stone and subtracting therefrom the weight of a mass of stone, equal in volume to the pore space of the given rock and of the same specific gravity.

A simpler method would be to compute the apparent specific gravity as directed above and multiply by 62.5, which should give the same result.

Effect of temperature changes.— The durability of a stone depends very largely upon its capacity to withstand temperature changes. Such changes may affect the mineral constituents of rock through expansion and contraction, or they may cause the interstitial water to freeze and thaw, on account of which the strength of the stone may be materially lessened.

Very few tests have thus far been made to determine the effect on building stone, of the alternate freezing and thawing of interstitial water. The importance of such experiments has never been questioned, but the difficulty of manipulation and the many conditions which need consideration before conclusions can be drawn from the quantitative results, have had the effect of almost excluding these tests from the experiments on building stone.

The effect of alternate freezing and thawing may manifest itself in three ways : first, cracks may form ; second, small particles or grains may be thrown off from the surface occasioning a loss in weight; third, the strength of the sample may be lessened. The first result is very seldom observed in testing samples in the laboratory, owing to the careful selection of the pieces tested. The other two, however, usually occur and can be measured quantitatively.

Two methods, known as the natural and the artificial, have been employed to determine the effect of alternate freezing and thawing of the interstitial water. The natural method is to soak the samples with water and alternately freeze and thaw them, a few or many times, at the convenience of the operator. The artificial method is to saturate the stone in a boiling solution of soluble salt, such as sodium sulphate, and then allow it to dry. As the water evaporates the salt crystallizes and expands, producing stresses similar to those which result from freezing water. It appears to me that the only instance in which it is excusable to use this method is when there is no opportunity to freeze the samples under conditions which more nearly accord with those which occur in nature.

For the purpose of testing stone according to the natural method, the operator should use two-inch cubes as in the

previous experiments. If the tests are made during the winter months when the temperature is below the freezing point, the samples can be saturated with water, cooled to nearly the freezing point, and then placed out of doors. If freezing temperatures do not prevail in the climate where the experiments are being performed, access may be had to a cold storage building where the necessary temperature may be obtained. Freezing mixtures may also be used to produce the desired temperature.

The samples to be tested should first be thoroughly cleaned and dried in a hot air bath at a temperature of 110° C. and weighed. After the samples are thoroughly saturated with distilled water, after the manner outlined in the specific gravity test, they should be cooled almost to the freezing point, taken from the water and removed to the place of freezing and allowed to remain for twenty-four hours. The samples should be thawed, saturated, and frozen alternately each day for a period of thirty or forty days, after which they should be placed in a hot air bath and dried at a temperature of 110° C. They should then be removed to the weighing room and weighed. This final weight subtracted from the first gives the loss in weight. The samples should be examined to discover any cracks that may have formed as a result of the freezing.

Finally the frozen cubes should be crushed in a testing machine to determine their compressive strength. The results thus obtained should be compared with the strength tests made on unfrozen cubes of the same stone.

The loss in weight during a period of thirty-five days has been found to be due mainly to the removal from the surface of small particles which were previously loosened, in the process of cutting the sample. Many of the grains at the surface of sandstone samples which have been sawed or hammer-dressed are partly loosened. Such grains fall away from the mass of the stone very easily. The pressure which is supplied by the freezing water, which fills the cracks and pores near the surface, is abundantly able to accomplish this.

Naturally, sedimentary rocks, such as sandstone, have more loose grains at the surface than the igneous rocks or finely crystalline limestone. However, in any case, alternate freezing and thawing for a period of thirty-five days will scarcely result in anything further than the removal of the loose particles from the surface. If the process is continued for another thirty-five days it is probable that in the case of sandstone the loss during this period will be far less than that of the first period. Even though the loss should be as great, the results could not be justly compared, except between the same kinds of stone.

To my knowledge, the loss in crushing strength due to freezing has not received the least consideration by any previous writer on building stones. As inferred above, I believe that the tests heretofore made to determine the loss in weight are of comparative little value in estimating the effect of freezing and thawing on the durability of a stone. The determination of the loss in crushing strength is obviously more important. It is evident that if a stone is saturated with water and frozen while a portion of the pores are still filled with water and the process is repeated a score or more of times, the adhesion of the particles will be weakened. It is not reasonable to suppose that the strains produced can be measured by the immediate loss in weight. It is plausible to suppose that the deterioration can be better measured by the loss in strength.

Experiments performed in the preparation of the report on the "Building Stones of Wisconsin" confirm my impression regarding the value of the crushing strength test applied in this manner. I feel quite confident that this test is more important than the determination of the loss in weight, and should, I believe, eventually take precedence in the testing of building stones.

Extreme heat.—Very few tests have been performed to ascertain the effect of heat or cold when applied directly to stone, yet it is known from observation that rapid and extreme changes in temperature weaken a rock and often cause disintegration. In large cities, the capacity to withstand extreme heat is one of

the essential qualities of a good building stone. In the conflagrations which have occurred in many cities, brick, stone, and wooden structures have suffered alike. Granite and brick walls have crumbled into shapeless masses, while iron beams and girders have been melted and twisted into all conceivable shapes.

A comparatively low temperature destroys some materials, while others are barely affected at a temperature above the melting point of copper. Most building materials, however, are destroyed when subjected to a very high heat.

It is known that rocks are poor conductors of heat, and for this reason the outer shell of a block may be very highly heated while the interior is comparatively cold. If a block is quickly cooled after heating, contraction of the outer shell takes place, and the differential stresses occasioned thereby rupture the rock.

The destruction caused by a conflagration is largely increased by streams of water which are thrown onto the burning buildings in an attempt to extinguish the flames. If the fire occurs in winter the effect is still further intensified by the freezing of the water.

Few experiments have thus far been performed to determine the temperature which the different kinds of stone will stand without injury. It has, however, been demonstrated that stone will withstand a much higher temperature when heated and cooled slowly than when heated and cooled rapidly.

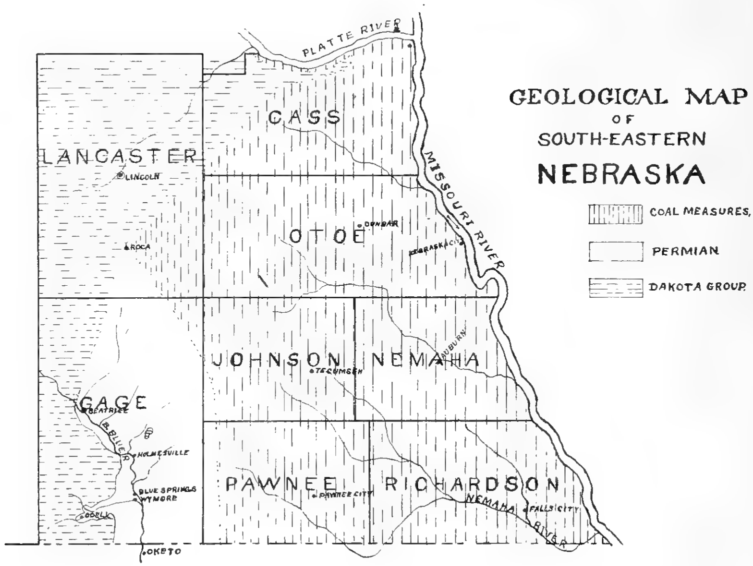
The easiest method to test the capacity of a stone to withstand heat is to place two-inch cubes in a muffle furnace and gradually heat them from a low to a high temperature. By using a standard pyrometer the temperature can be gauged and the visible effect of any increase in heat can be noted. Samples should be tested not only to ascertain the effect of gradual heating and cooling, but they should also be removed from the furnace and suddenly cooled by plunging into cold water.

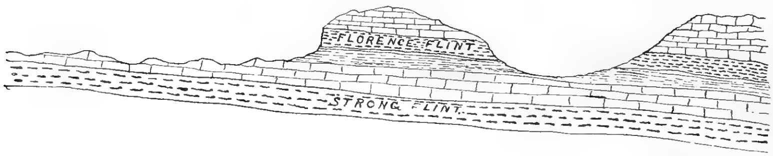
Limestone and dolomite are injured mainly through calcination, although when suddenly cooled they flake at the corners. Coarse grained granite is often shattered throughout its mass. Medium grained granite flakes at the corners, while the compact,

[To be inserted between pp. 356 and 357, May-June number, 1899.]

LIMESTONE QUARRY ABOVE FLORENCE FLINT. BLUE SPRINGS, NEB.

EXPOSURE OF FLORENCE FLINT IN A QUARRY EAST OF WYMORE, NEB.





A Geological Section of the Nebraska Permian from Beatrice South and East to the Kansas Line.

fine grained varieties are often traversed by sharply defined cracks. In contrast with the limestone and granite, sandstone has all outward appearance of being very little injured by extreme heat. However, it is often so soft after being subjected to extreme heat that one can crumble it between the fingers. The extent to which a coarse grained sandstone has been injured by extreme heat cannot be determined until the strength of the stone has been actually tested. All the stone that has been heated to a high temperature emits the characteristic ring, and scratch of brick. The cause for this may be found in the loss of the water of composition by the minerals of the rock.

Experiments seem to indicate that there are few, if any, stones, whether they be granite, limestone, or sandstone, that will effectually withstand a temperature of 1500° F. A rock with a uniform texture and a simple mineralogical composition apparently suffers the least injury when subjected to high temperatures.

It would be interesting to know the loss of strength occasioned by each increase in temperature of 100 or 200° for the different kinds of building stones. This can only be determined by a careful series of experiments, and it is hoped that in the future some one will undertake this task.

The effect of sulphurous acid gas.—Limestone, dolomite, and marble are the only kinds of stone which are to any extent injured by sulphurous acid gas. To determine the effect of this gas upon dolomite or limestone, two-inch cubes are dried at a temperature of 110° C. and carefully weighed. They are then placed in a wide mouthed bottle, in the bottom of which is placed a beaker of water to keep the air moist. The bottle is sealed and each day sufficient sulphur dioxide is transferred into the bottle to keep the atmosphere saturated. The samples should be allowed to remain forty-four days in this atmosphere saturated with sulphur dioxide. After being removed from the bottle the samples should be washed and thoroughly dried at a temperature of 110° C. They should finally be weighed and the loss in weight determined. The percentage of loss in weight is taken as the result. The loss in this case is due mainly to the

magnesium and calcium salts which collect at the surface and are dissolved by the water when the samples are washed.

Effect of carbonic acid gas.—The effect of carbonic acid gas on limestone is determined in the same manner as that of sulphurous acid gas. The samples are dried at a temperature of 110° C. and weighed. They are then placed in a wide mouthed bottle which is filled with carbonic acid gas. A beaker of water is placed in the bottle to keep the atmosphere moist. After being treated for forty-four days the samples are removed, washed, and weighed. The percentage of loss in weight is taken as the result.

Sulphur dioxide and carbon dioxide probably do not at any time exist alone in the atmosphere. The effect of these gases acting together or in conjunction with the many less abundant gases of the atmosphere may produce very different results than when acting separately.

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EDITORIAL

An unsigned article in *Science* (June 22) entitled "Sigma Xi at the American Association for the Advancement of Science," calls attention approvingly to a movement to associate meetings of this Greek-letter society with those of the Association. The rapid rise of the Sigma Xi in American universities is cited, and it is affirmed that "as an honor society it promises to take a leading part in our universities in which science holds a prominent place." It is urged that "it has become a representative honor society for the ablest students of science in the institutions where it is established." Respecting its intent, the following authoritative quotation is made: "In establishing a new chapter . . . . in each case we should make sure that we entrust the power of distributing the honor of membership only to such persons and institutions as are capable of giving the education and training necessary to the carrying on of scientific investigation."

It is scarcely necessary to make these quotations to show that the fundamental feature of the society is the promotion of a class distinction based on academic preparation. However laudable this may be, in itself considered, it would seem to be inharmonious with the fundamental purpose of the Association, which is the development and dissemination of science among all people without regard to race, age, sex, or previous condition of intellectual servitude. From professional relations the writer should not be inappreciative of the value of university training and of academic achievement. Nevertheless, it seems to him that the purposes of the Association are unqualifiedly democratic and that the spirit of science is equally so, and that therefore the only distinctions which the Association should foster or sanction, if it fosters or sanctions distinctions at all, are those which are based solely upon scientific productiveness. And this productiveness should be honored quite irrespective of its connection

with the fortunate conditions of academic appointments and opportunities, or with the adverse or even hostile conditions under which much good science has been developed. The movement therefore to connect the meetings of the Sigma Xi with those of the Association seems incongruous.

As set forth in another article in the same number of *Science*, some fifteen special scientific societies have already become correlated with the Association and have much increased the complexity of the proceedings. This movement seems to be an inevitable consequence of the differentiation of scientific work, and is scarcely less than necessary to the continued success of the Association, but it has already brought some inevitable conflict of interests and not a little congestion of programs and appointments. Between these and the increased number of social functions, it has already come to pass that there is little time left for that personal conference and that informal sociability whose basis is "shop talk," which formed so large a factor in the attractiveness of the earlier meetings of the Association. If now in addition to these laudable complications, the attention of a considerable number of the members of the Association is to be diverted in the interest of an academic honor society and a precedent established for the meeting of other societies whose basis is not strictly congenial to that of the Association, it is not clear where the limit of congestion will be found.

Between the lines of the article referred to, the imagination is tempted to read a hint of a desire for that rank and dominance in the Association which the members of Sigma Xi attained in university circles, and it is not unnatural to anticipate that the fraternity might unconsciously play a part in Association politics not unlike that for which Greek-letter societies are famous throughout the university world. To those who pride themselves upon rank and band themselves together because of rank it is not unnatural that official expressions of rank should be sought through the unconscious influence of fraternization.

It is not altogether foreign to the subject of this discussion to note the increasing encroachments of formal social functions

upon the meetings of the Association and not less perhaps upon the meetings of the Geological Society of America. Without doubt a certain measure of formal contact with general society is helpful to the ends sought by the Association. At the same time it must be recognized that formal social functions are largely the province of the leisure class and that from the very nature of the case they must remain so, for leisure and the means of leisure are prerequisites to their effective cultivation. Equally from the nature of the case, the devotees of science do not usually belong to the leisure class because real success in science involves strenuous endeavor and an almost unlimited devotion of time. The diversion of time to social functions during the meetings of the Association should, therefore, be zealously watched and restrained within limits which are compatible with the efficient conduct of the primary purposes of the Association. Particularly is this true of the Geological Society which has no organic relation to general society. The movement in the direction of social formality has already crowded hard upon the point where the first requisite preparation for a meeting of the Association or of the Geological Society is the packing of a dress suit, and the second is the preparation of an after-dinner speech, preparations that are none too congenial to the great mass of hard workers in science.

T. C. C.

Reviews

The Illinois Glacial Lobe. By Frank Leverett, Monograph XXXVIII, U. S. Geological Survey, pp. 817. Plates XXIV, 9 figures. Washington, 1899.

This is one of a series of monographs in course of preparation by the Glacial Division of the United States Geological Survey, whose purpose is to set forth the salient features of the glacial formations preparatory to more detailed mapping by quadrangles, which the survey is undertaking, and by counties and other appropriate divisions, which many of the states are prosecuting. In a sense it may be said to be the first monograph of the systematic series. Two other monographs have been published, namely, that on Lake Agassiz, by Mr. Warren Upham, and that on the Glacial Gravels of Maine, by Professor George H. Stone, but these are special treatises on phenomena of exceptional interest and only indirectly form a part of the systematic series intended to cover the glacial area. The plan of the Survey departs somewhat widely from that prevalent in Europe where glacial work proceeds largely by minute studies of small areas without previous determination of the great features and broader classifications which can only be worked out by connected studies over large areas. The method of the United States Geological Survey has been to determine first these grand features and leading classifications and then descend in natural order to local details and more refined studies. Local mapping proceeds at great disadvantage without such preliminary determinations, for such is the nature of the glacial formations that these larger expressions of the phenomena of the period are very imperfectly expressed within any restricted area, and are quite beyond satisfactory interpretation unless the studies are extended beyond them.

The general reconnaissance work of the survey was essentially completed some years ago by the geologist in charge and the work of preparation of the monographs, as the second step of the plan, is now well under way. Besides the monograph under consideration, the manuscript of an additional one has been submitted and work upon a third is in progress.

The products of the Illinois glacial lobe constitute a natural monographic theme, for the differentiation of the border tract of the ice by the topographic influences of the trough of Lake Michigan gave the lobe a quite distinct individuality. In the monograph, however, for convenience the field is rather arbitrarily limited on the north where the products of the Illinois lobe become complicated on the east side with those of the Huron-Erie and the Saginaw lobes and on the west side with those of the Green Bay lobe. This limitation, however, does not seriously affect the unity of the theme. This lobe was given precedence because its field embraces the most southerly reach of the great ice mantle and because its products are unusually well deployed.

The author's abstract of the monograph which follows, sets forth its contents better than could be done by another.

Chapter I. Introduction.— The Illinois glacial lobe formed the southwestern part of the great ice field that extended from the high lands east and south of Hudson Bay southwestward over the basins of the Great Lakes and the north-central states as far as the Mississippi valley. It overlapped a previously glaciated region on the southwest, whose drift was derived from an ice field that moved southward from the central portion of the Dominion of Canada as far as the vicinity of the Missouri River. This southwestern part of the eastern ice field, being mainly within the limits of the State of Illinois, has received the name Illinois Glacial Lobe.

The results of earlier studies by Chamberlin, Salisbury, and others are noted, and the plan of investigation is set forth. A brief explanation of the method of numbering townships is presented.

Chapter II. Physical features.— The variations in altitude are set forth in a topographic map and also in tables, and the marked increase in altitude of certain parts of the region because of drift accumulations is considered. The conspicuous reliefs of the rock surface are briefly touched upon, and the preglacial valleys receive passing notice. Profiles and maps are extended across the bed of Lake Michigan as well as border districts, and the inequalities of the lake basin are briefly discussed.

Chapter III. Outline of time relations or glacial succession.— A sketch of the major and minor divisions of the drift sheets and of the intervals between them is accompanied by a brief explanation of the basis for the classification adopted.

Chapter IV. The Illinoian drift sheet and its relations.— The Illinoian is the most extensive drift sheet formed by the Illinois glacial lobe and receives its name because of its wide exposure in the State of Illinois. The evidence that the Illinoian drift sheet should be separated from the outlying and underlying drift is briefly set forth. The aspects of the Illinoian drift

sheet are then discussed, its topography as well as its structure being considered. In connection with this drift sheet a very adhesive clay known as "gumbo," which caps it, is described and the questions of its relation to this drift sheet and to the overlying loess are considered. A detailed description of the border of the Illinoian drift sheet is then given, which is followed by a description of the moraines and other drift aggregations back from the border.

Remarkable instances of the transportation of rock ledges are noted. The striæ pertaining to this invasion are discussed in some detail. The effect of this ice invasion and its drift deposits upon the outer-border drainage is touched upon, but the detailed discussion of the influence of the drift upon drainage is deferred to a later chapter. The chapter closes with a discussion of the deposits which underlie the Illinoian drift sheet.

Chapter V. The Yarmouth soil and weathered zone.— A well-defined soil and weathered zone which appear between the Kansan and Illinoian drift sheets in the overlap of the latter upon the former are described, and sections are represented which show clearly the relations to these drift sheets. The amount of erosion effected during the interglacial stage is also considered. The name Yarmouth is taken from a village in southeastern Iowa, where the interglacial features were first recognized by the writer.

Chapter VI. The Sangamon soil and weathered zone.— Another well-defined soil and accompanying weathered zone which appear between the Illinoian drift and the overlying loess are described. The name Sangamon is applied because these features are exceptionally well developed in the Sangamon River basin in Illinois and were there first noted by Worthen in the early reports of the Illinois Geological Survey.

Chapter VII. The Iowan drift sheet and associated deposits.— The name Iowan was applied by Chamberlin to a sheet which is well displayed in eastern Iowa and which had been brought to notice by McGee. The chapter opens with the discussion of a drift sheet of a similar age which was formed by the Illinois lobe, its extent, topographic expression, and structure being considered. The relation of this ice lobe to the Iowa ice lobe, and the relation of each to the great loess deposit of the Mississippi basin are then considered, after which the loess is discussed. The problem of the mode of deposition of the loess forms the closing topic.

Chapter VIII. The Peorian soil and weathered zone (*Toronto formation*). The name Toronto formation, suggested by Chamberlin, for interglacial deposits exposed in the vicinity of Toronto, Canada, may prove to be applicable to a soil and weathered zone which appear between the Iowan drift sheet or its associated loess and the Shelbyville or earliest Wisconsin drift sheet which overlies the Iowan. Exceptionally good exposures of a soil and weathered zone at this horizon in the vicinity of Peoria, Ill., make it seem

advisable to apply the name Peorian, while the relations of the Toronto formation remain uncertain, Other exposures as well as those near Peoria are discussed. A marked interglacial interval between the Iowan and Wisconsin stages of glaciation may also be inferred by a comparison of the outline of the ice sheet at the Iowan stage of glaciation with that of the outline at the culmination of the Wisconsin stage. It may also be inferred by a change in the attitude of the land, by which better drainage conditions were prevalent in the Wisconsin than in the Iowan stage.

Chapter IX. The early Wisconsin drift sheets. — The Wisconsin drift, named by Chamberlin from the state in which it was first recognized as a distinct drift, is characterized by large morainic ridges and comparatively smooth intervening till plains which have been thrown into two groups, known as the early Wisconsin and late Wisconsin. In the first group the moraines form a rudely concentric series, which are well displayed in the northeastern part of Illinois, but are largely overridden by the moraines and drift sheets of the later group in districts farther east. The outer border of the second, or late, Wisconsin group is so discordant with the moraines of the first group that there seems in this feature alone sufficient reason for separation.

The several morainic systems of the early Wisconsin group are taken up in succession from earlier to later, the distribution, relief, range in altitude, surface contours, thickness and structure of the drift, and the character of the outwash being considered. In connection with each morainic system the associated till plains are discussed, attention being given to the surface features and to the structure and thickness of the drift. In northern Illinois the several morainic systems are merged into a composite belt so complex that it is difficult to trace the individual members.

The several moraines and their associated sheets of till do not appear to be separated by intervals so wide as are found between the Illinoian and Iowan or the Iowan and Wisconsin drift sheets. Indeed, instances of the occurrence of a soil or a weathered zone between Wisconsin sheets are very rare. There may, however, have been considerable oscillation of the ice margin.

Chapter X. The late Wisconsin drift sheets. — The basis for separation from the early Wisconsin is first considered, after which the several morainic systems and their associated till plains are taken up in order as in the discussion of the early Wisconsin drift. An interpretation of the Kankakee sand area is attempted, though several questions connected with it still remain open. The chapter closes with a discussion of the striæ found within the limits both of the early and of the late Wisconsin drift.

Chapter XI. The Chicago outlet and beaches of Lake Chicago. — That a body of water once extended over the low districts bordering the southern end of Lake Michigan and discharged southwestward to the Des Plaines and thence into the Illinois River has been recognized since the early days of

settlement, and several papers discussing the beaches and the outlet have appeared. The latter has long been known as the Chicago outlet, because it led away from the site of that city. The lake has recently been given a name in harmony with that of the outlet (Lake Chicago).

After reviewing the previous reports and papers, the Chicago outlet is described in some detail. The several beaches of Lake Chicago are then taken up in order from highest to lowest. The chapter ends with a discussion of the present beach of Lake Michigan.

Chapter XII. Influence of the drift on drainage systems and drainage conditions.— It is shown that many drainage systems are entirely independent of the preglacial lines, while others are independent only in part, a considerable part of their courses being along the lines of old valleys. The development of drainage systems is shown to be much farther advanced on the Iowan and Illinoian drift sheets than on the Wisconsin. This is found to be due to differences in age, and not to natural advantages for discharge. The Wisconsin is, on the whole, more favored by uneven surface for the rapid development of drainage lines than the Illinoian. The several drainage systems are discussed in considerable detail.

Chapter XIII. Average thickness of the drift in Illinois.— Illinois affords an especially good opportunity for the estimate of the thickness of the drift, because of the large number of well sections obtained, and because of the comparative smoothness of the region. The inequalities of the rock surface beneath drift plains may be estimated by the study of neighboring driftless tracts, as well as by borings and outcrops within the drift-covered area. There are thus two quite different methods by which the average thickness of the drift may be ascertained.

The first method here used is that of averaging the results of borings and outcrops. These are averaged in each township in which the distance to rock is known, and the results are then combined for the average of all the explored townships. Consideration is then given to the distribution of the explored townships in reference to drift plains and moraines and to preglacial uplands and valleys, and necessary corrections are made. By this method the thickness of the drift is found to be not less than 100 feet, and it may be 120 feet or even more.

The second method, based upon a comparison of the Illinois drift area with the neighboring driftless tracts, gives 129.3 feet as the average thickness, or slightly more than the highest results obtained by the first method. Combining the two methods, the average thickness of the drift of Illinois can be placed at not more than 130 feet and not less than 100 feet.

An attempt is made to estimate the part contributed by each ice invasion, but the data prove to be scarcely complete enough for a good estimate. It is found that the general thickness within the limits of the Wisconsin drift is 40 to 45 feet greater than in the portion of the state outside.

Chapter XIV. The wells of Illinois.—This chapter aims to present all the reliable well records obtained within the state which throw light upon the deposits penetrated, as well as upon the character of the water supplies. In addition to the wells which terminate in the drift, there are included many which extend deeply into the underlying rock formations. This necessitates a classification of the underground waters and a description of the several rock formations penetrated, including a discussion of the attitude of the strata. The essential conditions for obtaining artesian wells are considered, and also the relation of the drift to the ordinary wells. There is a brief discussion of gas wells, confined mainly to those obtained in the drift. A tabulation of sources for city water supply is then presented, after which there appears a detailed discussion of wells, taken up by counties.

Chapter XV. Soils.—The sources of soil material are first discussed. An attempt is then made to classify the soils according to their origin. Eight classes are recognized as follows: Residuary soils, bowlder clays, soils, gravelly soils, sandy soils, bluff-loess soils, silts slowly pervious to water, fine silts nearly impervious, peaty or organic soils.

The matters of chief general interest will doubtless be found in the classification of the glacial series, in the changing configuration of the ice at its successive stages, in the differences of the deposits at the different stages, and in the estimate of the average thickness of the drift.

In the matter of classification, the monograph presents the latest and fullest expression of the conclusions toward which investigations in the interior have been steadily tending for the past decade. The classification offered is not regarded as final, either in the sense of including all the possible great divisions, or in the complete characterization of those recognized, but it clearly lies in the line of a true and ultimate classification. Fifteen stages are recognized, six of which are based upon notable glacial advances, five represent notable intervals of deglaciation, and four are based upon lacustrine stages after the beginning of the abandonment of the region by the last ice-sheet. The age of the oldest glacial formation is regarded as many times that of the latest; and the oldest interglacial intervals are also believed to be many times longer than the later ones. In a word, the oscillations appear to have been large in the earlier stages and to have grown less and less during the progress of the period. This newer view of the relative ages of the successive epochs, sustained as it appears to be by the progress of research in Europe, must be looked upon as one ofthe most important advances of recent years, for

it affects profoundly nearly all of the larger questions of glacial history.

The distinction between the ages of the several glacial sheets is founded upon careful estimates of the amounts of erosion they have respectively suffered, upon the depths and extent of the weathering process as exhibited alike in the clays and in the pebbles and bowlders, upon the degree of constructive mineralization in the form of segregates and general induration of the deposits, upon the extent of interglacial accumulations of soil, peat and similar deposits, and upon the nature of the life which occupied the region between the glacial stages, together with incidental criteria of more special nature and limited application. When it is considered that the broad sheet of Kansan till, which shows indubitable evidence of having been spread out as an approximately plane sheet, has been so thoroughly eroded over very large areas that only remnants of the original plane remain here and there, it is impossible for the candid mind to resist the conviction that it is very widely separated in age from the later drift-sheets which have been merely ditched by the water courses, leaving scattered over the broad, scarcely modified surfaces, multitudes of shallow basins which a few feet of cutting would completely drain.

While not new, the monograph brings out into sharp definition the lobate character of the ice margin at all of its stages. At the same time it shows that there was a change in the configuration of these lobes at different stages. It is perfectly clear from the general nature of these configurations that they are fundamentally dependent upon the topography of the region they occupy and of that which lies backward along the line of glacial invasion. At the same time there are some anomalies which, while not defiant of topography, do not clearly show their dependence upon it and indicate that other factors than topography were involved in determining the development of the ice lobes. These other agencies are very likely climatic, but they have not yet been deciphered. The most notable of these anomalies are the peculiar forms assumed by the Iowan drift and the shifting in the contours of the lobes between the earlier and later Wisconsin stages.

Closely allied to this variation in configuration is a remarkable variation in the mode of action of the ice at different stages to which the monograph contributes a large mass of data. The earlier drift-sheets

are spread widely over the country without evidences of profound abrasive action upon the pre-existing surface, not that such action was absent, but it was far less vigorous than in the later stages. In harmony with this milder action upon the face of the country invaded, the drift-sheet itself was spread much more uniformly than in later times and pronounced morainic ridges are much more rare, and when present are much feebler and less characteristic. At the same time, the glacial drainage appears to have been much less vigorous and in some instances surprisingly lacking in vigor. These phenomena are among the most suggestive that yet await causal explanation.

By far the most careful and trustworthy estimate of the average thickness of the drift which has heretofore been made in this country is embraced in chapter XIII of this monograph. Not only are the data much more ample and better distributed than those that have heretofore been at command, but they have been analytically classified and discussed by more critical methods. The most difficult element of the problem is the drift embraced in the preglacial valleys, the depth and configuration of which it is difficult to estimate. This has been attempted, however, along two different lines which give essential concordant results, and it is a fair presumption that the total estimate of the mass of the drift of the region investigated is a not distant approximation to the real facts. How far the territory of the Illinois glacial lobe is representative of the average thickness of the drift throughout the glaciated region cannot now be determined, for if the great Canadian tract be embraced, as it should, our knowledge is best defined by emphasizing its limitatations; but the average thickness in Illinois may rudely represent the average thickness for areas similarly situated near the border of the glaciated area, but even this cannot be confidently affirmed.

The work of Mr. Leverett is conspicuous for the judicial attitude of mind which eminently controls it. The emotional factor is held in marked abeyance and the intellectual factor suffers little trammeling from predilections. At the same time the large area covered by critical study testifies to an industry which could not have been greatly enhanced by emotional enthusiasm. The monograph will be best appreciated by those who are most familiar with the ground.—T. C. C.

Preliminary Report on the Copper-bearing Rocks of Douglas County, Wisconsin. By ULYSSES SHERMAN GRANT, Ph.D. Wisconsin Geological and Natural History Survey, Bulletin No. VI. Economic Series No. 3, pp. 55. 1900.

The report is the result of field work during the summer of 1899, and deals in a preliminary way with the St. Croix and Douglas copper ranges of Douglas county, Wisconsin. It contains four geological maps and several illustrative plates. Chapter I outlines the geology of the county and contains a sketch of the three rock series represented; namely, the Cambrian, the Upper Keweenawan, and the Lower Keweenawan. The Lower Keweenawan consists of igneous rocks, largely basic lava flows with a few interbedded conglomerates. The copper deposits are usually at or near the contacts of the flows, and the author has given some of the characteristics by which the contacts may be known. The Upper Keweenawan consists of conglomerates, sandstones and shales, lying apparently conformably upon the igneous beds and dipping southeast at low angles. The Lake Superior sandstone underlies the northern part of the county, and consists essentially of quartz sand, but in some places becomes conglomeratic, and in others clayey or shaly. Its junction with the Lower Keweenawan is marked by a fault of considerable displacement along which the traps are shattered. Chapter II describes some of the more important outcrops of the St. Croix range and chapter III treats the Douglas range in a similar manner.

The last chapter is a "brief discussion concerning the mode of occurrence of the copper, where to search for copper, and the value of the deposits." This chapter is of special value to the prospector and the investor. On pages 53 and 54 are given several analyses of copper-bearing rocks from the two ranges. R. D. GEORGE.

Upper and Lower Huronian in Ontario. By ARTHUR P. COLEMAN. Bulletin of the Geological Society of America, Vol. XI, pp. 107–114. 1900.

In his work as geologist for the Ontario Bureau of Mines the author has gathered much material bearing on the problem of the Huronian in Ontario. In tracing the Michipicoten iron range it was found that the band of siliceous rock associated with it, and generally resembling

sandstone, passes at times into cherty and jaspery and quartzitic facies. The same association of siliceous rock and iron ore is found near Pic River, near Rainy Lake and on Rainy River, and near Rat Portage. Jaspery material like that of Michipicoten is found interbedded with iron ores near Lakes Wahnapitae and Temagami, between Sudbury and the Ottawa River. "If, as seems probable, these jaspers are the equivalents of the western Huronian sandstones, we have a definite horizon, traceable from point to point across the whole northern end of the province" which will be "a most valuable thread with which to unravel the much disturbed and complicated series of Huronian in Ontario." The conglomerates frequently found near the iron-bearing series and containing sandstone, chert, or jasper, identical with those of the iron-bearing series, have a similar range from east to west across the province and are thought to mark the greatest break in the Huronian series, or, in other words, to form the basal conglomerate of the Upper Huronian.

The author shows that if these conclusions are well founded we have "a means of correlating the widely separated and very different looking rocks mapped as Huronian in Ontario. Applying these conclusions to the Shoal Lake district, a part of Lawson's Keewatin is of Huronian age. They may also lead to a more certain correlation of the pre-Cambrian rocks of Ontario and the Wisconsin-Minnesota region."

R. D. GEORGE.

Mesozoic Fossils of the Yellowstone National Park. By T. W. STANTON. An extract from "Geology of the Yellowstone National Park," Monograph XXXII of the U. S. Geological Survey, Part II, Chapter XIII. Washington, 1899.

This chapter forms a valuable contribution to our knowledge of the Mesozoic faunas. The collection of invertebrate fossils described in it consists of seventy-eight species, having a distribution as follows: thirty-one are Cretaceous, forty-six are Jurassic, and one is possibly of Triassic age. The last specimen, a species of *Lingula* resembling *L. brevirostris* of Jurassic age, occurs in the Teton formation which occupies the stratigraphic position between the known Carboniferous and the undoubted Jurassic. This paleontologic evidence is considered too slight to form the basis of a correlation of the Teton with the Triassic of other areas.

The Jurassic assemblage forms the most important element of the collection. The two chief fossiliferous areas are: the one in the northwest corner of the Park, on the head waters of the Gardiner and Gallatin Rivers; and the other on the slopes of Sheridan Peak and farther southwest of Snake River. Two zones, characterized more by lithological than faunal peculiarities, are to be recognized, but the fossils belong to a single fauna.

The upper zone is marked by an arenaceous limestone yielding an abundance of *Rhynconella gnathophora*, *R. myrina*, *Ostrea strigilecula*, *Camptonectes bellistriatus*, and *C. pertenuistriatus*. The lower zone is characterized by calcareous clays and marls containing the majority of the above forms associated with *Pleuromya subcompressa*, *Pholadomya kingi*, and *Gryphea calceola* var. *nebrascensis*.

I found very similar zones in the Freeze-Out Hills of Wyoming, but they were characterized by slightly different assemblages of fossils. The upper zone consisted of clays and arenaceous limestones containing *Pentacrinus astericus* in abundance, and *Asterias dubium*, *Camptonectes bellistriatus*, *C.* (*extenuatus*) *pertenuistratus*, and *Ostrea strigilecula*. In the lower zone occurred clays and marls with calcareous nodules yielding *Astarte packardi*, *Pinna kingi*, *Pleuromya subcompressa*, *Pholadomya kingi*, and other forms. *Belemnites densus* and *Pentacrinus astericus* is common to both zones.

As these zones are both extremely narrow, are composed largely of clastic material, and contain an assemblage of fossils in many instances common to both, I think the conclusion that but a single fauna is represented is the correct one. This conclusion in regard to the Yellowstone region Dr. Stanton extends to the entire Jurassic formation of the Rocky Mountain region, and concludes as follows: "The stratigraphic relations and the geographic distribution of the marine Jurassic of the Rocky Mountain region are in favor of the idea that all of these deposits were made contemporaneously in a single sea."

A thin stratum of limestone in a position above the Jurassic beds and not far below the base of the Cretaceous section contains fresh water gastropods and Unios. The formation which contains this limestone is referred with considerable doubt to the Dakota. It is thought that it may be the equivalent of the Kootenai or Como. A similar limestone stratum occupying approximately the same stratigraphic position is found in the Como of Wind River, of the Black Hills, and the writer found it also in the Freeze-Out Hills. In all these localities

it contains a fresh water fauna consisting of gastropods and Unios, and in some instances species common to two or more localities.

The Colorado formation is represented by a characteristic fauna, consisting for the most part of Inocerami. The Montana formation is recognized, but its divisions are not easily differentiated. It seems probable that only the lower part of the Montana is represented.

In all, thirteen new species are figured and described. The majority of these belong to the Jurassic.

W. N. LOGAN.

The Glacial Gravels of Maine and their Associated Deposits. By GEORGE H. STONE. Monograph XXXIV, U. S. Geological Survey, 499 pp., 52 plates, 36 figures. Washington, 1899.

The enthusiastic pursuit of kames and eskers through the forests of Maine without official aid, in the later seventies, by Professor Stone, led to his engagement for a monographic study of all the glacial gravels of that phenomenally rich region by the U. S. Geological Survey. The results appear in this monograph. It would be an error, however, to overlook the second half of the title, for much attention is given to the formations associated with the glacial gravels, and tributary to their formation, so that the volume falls little short of being a monograph on the Pleistocene deposits of Maine.

So far as present knowledge extends, two regions surpass all others in the richness of their esker or osar phenomena—Maine on this continent, and Sweden on the eastern. This singular distribution is perhaps due to a critical relation between the general slope of the land surface in these regions and the minimum gradient at which glacier ice flows effectively, so that a condition of approximate stagnation was assumed in the closing stages of glaciation and the internal drainage lines of the ice sheet were permitted to develop with exceptional facility. However that may be, Maine is certain to be the classic field for esker studies in this country.

The plan of the volume embraces a preliminary discussion in which the fundamental facts of surface geology as illustrated in Maine are set forth with considerable fullness (chapters I, II, and III). The operative agencies are discussed in close connection with the phenomena described. This is followed by a general description of the systems of glacial gravels (chapters IV, and V). By systems is to be understood

those connected series of gravel ridges that are interpreted as the products of individual drainage systems of the ice sheet, the products of each river system being a gravel system. Some forty odd systems of this kind are recognized besides several less defined series and numerous branches and individual eskers, making on the whole a most phenomenal record of glacial drainage. The description of these occupies 170 pages.

The classification of the gravels and associated deposits and a discussion of their genesis follows and constitutes essentially the remainder of the volume (chapters v and vi, 224 pages). The discussion of the genetic element is elaborate and detailed. Something of the range of special subjects may be gathered from the following special themes: Quantity of englacial débris; distinction between englacial and subglacial tills; the origin of drumlins; the relations of the marine gravels; bowlder fields and bowlder trains; single or multiple glaciation in Maine; the relation of the glacial waters to the glacial sediments; the sizes of the glacial rivers of Maine; the zones of the Maine ice sheet; englacial streams; the directions of subglacial and englacial streams under existing glaciers; the internal temperatures of ice sheets; the basal waters of ice sheets; basal furrows as stream tunnels; the genesis and maintenance of subglacial and englacial channels; the forms of glacial channels; extraordinary enlargements of glacial river channels; the directions of glacial rivers compared with the flow of ice; the relations of glacial rivers to the relief forms of the land; sedimentation in places favorable or unfavorable to the formation of crevasses; glacial potholes; the formation of kames and osars; the bowlders of the glacial gravels; comparative studies on the glaciation of the Rocky Mountains and on the glaciers of Alaska; the modification of the glacial gravels by the sea; the short isolated osars or eskers; the hillside osars or eskers; the isolated kames or eskers ending in marine deltas; isolated osar-mounds not ending in marine deltas; the disconnected osars; the relations of glacial gravels to the fossiliferous marine beds; retreatal phenomena of the ice; causes of non-continuous sedimentation within the ice channels; the continuous osars and their comparison with discontinuous osars; were osars formed by subglacial or superglacial streams? tests of subglacial and superglacial depositions; special features and their explanation.

The illustrations are numerous and add greatly to the value of the text, and the large list of maps set forth the remarkable distribution of the gravel systems.

The work is characterized by enthusiasm and a pervasive desire to explain in fullness and detail all of the phenomena presented. The observational and the rational go hand in hand and each lends interest to the other.

T. C. C.

Lower Cambrian Terrane in the Atlantic Province. By C. D. Walcott, Proceedings of the Washington Academy of Sciences. Vol. I, pp. 301–339. February 14, 1900.

The object of the paper, as stated by the author, is to show the stratigraphic relations and successions of the Cambrian faunas of the Atlantic province. In the author's correlation paper on the Cambrian (Bull. 81, U. S. Geol. Surv. 1891), reference is made to unsolved problems of the Cambrian of this province. Mr. G. F. Matthew's study of these problems has led him to conclusions not in accord with those tentatively set forward by Mr. Walcott. He finds the Etcheminian beds at Hanford Brook unconformably below the Protolenus zone and regards them as a pre-Cambrian Paleozoic terrane, and makes a twofold division of the Cambrian of the Atlantic province as follows:

Upper Cambrian, - - -	Dictyonema fauna. Peltura fauna. Olenus fauna.
Lower Cambrian, - - -	Paradoxides fauna. Newfoundland species described. Protolenus fauna.

Mr. Walcott, having made a careful study of the Hanford Brook and other localities cited by Mr. Matthew in support of his position, notes the absence of Etcheminian débris in the overlying St. John quartzite, the absence of an irregularly eroded surface on the Etcheminian beds, and the evidence of overlap of these beds on the subjacent Algonkian, and holds that the patchiness and variation in thickness of the Etcheminian may be the result of deposition of sediments upon a very irregular sea-bottom, and not of erosion as held by Mr. Matthew. Mr. Walcott believes the distinctive features of the Etcheminian fauna pointed out by Mr. Matthew do not necessarily separate it from the

Lower Cambrian. The paper closes with the following conclusions:

"(*a*) The 'Etcheminian' terrane of Matthew is of Lower Cambrian age.

"(*b*) The Olenellus fauna is older than the Paradoxides and Protelenus fauna of the Middle Cambrian.

"(*c*) The Cambrian section of the Atlantic Province of North America includes the Lower, Middle, and Upper Cambrian divisions as defined by me in 1891."

R. D. GEORGE.

Forest Reserves. Part V of the Nineteenth Annual Report of the United States Geological Survey. HENRY GANNETT, Chief of Division, Washington, D. C., 1899.

This report consists of the following parts: The forests of the United States, by Henry Gannett; Black Hills Forest Reserve, by H. S. Graves; Big Horn Forest Reserve, by F. E. Town; Teton Forest Reserve, from notes by F. S. Brandegee; Yellowstone Park Forest Reserve, from notes by F. S. Brandegee; Priest River Forest Reserve, by J. B. Leiberg; Bitterroot Forest Reserve, by J. B. Leiberg; Washington Forest Reserve, by H. B. Ayers; Eastern Part of Washington Forest Reserve, by M. W. Gorman; San Jacinto Forest Reserve, by J. B. Leiberg; San Bernardino Forest Reserve, by J. B. Leiberg; San Gabriel Forest Reserve, by J. B. Leiberg: Forest conditions of Northern Idaho, by J. B. Leiberg; Pine Ridge Timber, Nebraska, by N. H. Darton.

According to the report there are in the United States, exclusive of Alaska, 1,094,496 sq. miles of wooded land, or in other words 37 per. cent of the total area is wooded. The total value of the forest product of the country for 1890 was 800 million dollars which is an amount slightly in excess of its mineral production. The total amount of sawed lumber consumed was 23,500 million feet B. M., and the amount used for fuel was 180,000 million feet B. M.

The sources of injury to forests are classed under the categories of fires, winds, lightning, insects, and wasteful methods of lumbering. The necessity for better forest management is urged in order to prevent waste, and to establish forests in the place of those being depleted for legitimate purposes. It is urged that the object of forest management should be to produce forest products in as short a time

as possible, to establish if possible a system of forestry which will produce lumber timber in less than 150 years, and mine timber in less than 100 years.

The principal subjects discussed in the several divisions of the report embrace the topography, the limits, the agricultural lands, the mining and the forests of the reserves. Other topics include the water supply, parks species of timber, classification of timber, amount of available timber, and means of transportation of lumber.

The report is furnished with an excellent set of illustrations and maps. It is a valuable contribution, well calculated to accomplish the purposes for which it was written, *i. e.*, to furnish as full data as possible concerning our forests, and to waken a desire for their preservation.

W. N. Logan.

Geology of Narragansett Basin. By N. S. Shaler, J. B. Woodworth and A. F. Foerste. Monograph XXXIII, U. S. Geological Survey, pp. xx + 394. 1900.

The Monograph is divided into : Part I, General Geology of the Narragansett Basin, by N. S. Shaler; Part II, Geology of the Northern and Eastern Portions of the Narragansett Basin, by J. B. Woodworth, and Part III, Geology of the Carboniferous Strata of the Southwestern Portion of the Narragansett Basin, with an account of the Cambrian deposits, by Aug. F. Foerste.

The stratified rocks of the basin range from Cambrian to Carboniferous. The structure of the basin makes it appear probable that it originally contained an extensive development of pre-Cambrian rocks. Upon these were laid down the lowest Cambrian beds. The Middle Cambrian is not represented in the region south of Braintree. The Upper Cambrian is represented only by pebbles of quartzite in the conglomerates. While only the Lower Cambrian is found in situ, pebbles of Middle and especially of Upper Cambrian are so abundant as to lead to the statement that "there appears to have been nearly continuous deposition in this field throughout the Cambrian period." The Silurian and Devonian do not appear to be represented in the Narragansett Basin. Upon the Cambrian strata and the eruptive granites come the Carboniferous strata which occupy the greater part of the basin. It is probable that the earliest Carboniferous rocks of the basin are the upper part of the Coal Measures, and it is possible that the upper conglomerates of the basin may be Permian. The basin was probably

partly formed before Carboniferous time. Professor Shaler believes that east of the Appalachians there were developed during Carboniferous times a great series of erosion troughs which by sedimentation and subsidence became centers of quaquaversal orogenic movement, resulting in foldings with axes variously inclined to one another within the same trough. The truncated remains of the folds so produced are to be seen at various points along the Atlantic seaboard. That these erosion troughs were river valleys and estuaries is suggested by their lack of parallel or other definite arrangement such as is seen in the Appalachians, as well as by the character of the deposits they contain. The Narragansett basin is one of these ancient erosion troughs in which the folds were of the anticlinal and synclinal type. The present average structural depth of the basin is placed at 7000 feet, but it is assumed that this depth is due mainly to folding resulting from accumulation of deposits. The source of the bulk of the sediments of the basin was the immediately surrounding granitic, trappean, schistose and other rocks. There are also many quartzitic pebbles of Cambrian age in the conglomerates but the source of the similar pebbles of the drift is considered unsettled. In discussing the glacial history of the region Professor Shaler expresses the view that this district was one of extensive and long continued glaciation during the Carboniferous period and that the important features of the upper stratified rocks are due to glacial action.

In the economic section the soils, coals, and iron ores are discussed at considerable length. Recent subsidence in the immediate vicinity of the basin has caused flooding of old valleys. This and the thick covering of drift have rendered geological work difficult, and the delimitation of formations uncertain. The volume represents much detailed work accomplished in a region presenting more than ordinary difficulties. There are many well placed plates and figures to illustrate the text.

R. D. George.

On the Lower Silurian (*Trenton*) *Fauna of Baffin Land.* By Charles Schuchert. Proceedings of the U. S. National Museum. Vol. XXII, pp. 143–177, with plates XII to XIV.

At the request of the author, Mr. J. N. Carpender and others (who accompanied the Seventh Peary Arctic Expedition as far as Baffin Land in 1897,) made collections of fossils from Silliman's Fossil Mount at

the head of Frobisher Bay. The fossils are well preserved and many of them are now in the U. S. National Museum. The paper gives a brief summary of the geology of the region as gathered from reports by those who have either visited it or have examined collections from it. The Lower Silurian fossils so far collected are of Trenton and Utica age, and strata containing these faunas are widespread in eastern Arctic America. So far as known they rest upon the pre-Cambrian rocks and are overlain by beds of Niagara age. Of the 72 species known from the locality of Silliman's Fossil Mount 28 are restricted to it. Of the remaining 54 species, 41 are found in the Manitoba-Minnesota-Wisconsin region and 17 in the New York-Ottawa region. A comparison of the 54 species found elsewhere with those from definite stages in Minnesota shows that 10 are found in the Birds-eye (Lowville), 17 in the Black River, 38 in the Galena, and 11 in the Cincinnatian.

The close resemblance of the Minnesota Galena to the Silliman's Fossil Mount formation may in large part explain the close identity of the faunas. In the summary, page 175, the author says: "The Baffin Land fauna had an early introduction of Upper Silurian genera in the corals Halysites, Lyella and Plasmopora. In Manitoba similar conditions occur in the presence of Halysites, Favosites, and Diphyphyllum. The Trenton fauna of Baffin Land shows that corals, brachiopods, gastropods, and trilobites have wide distribution and are therefore less sensitive to differing habitats apt to occur in widely separated regions. On the other hand the cephalopods and particularly the pelecypods, indicate a shorter geographical range. The almost complete absence of Bryozoa in the Baffin Land Trenton contrasts strongly with the great development of these animals in Minnesota and elsewhere in the United States."

The paper is a valuable addition to our knowledge of the Ordovician faunas of eastern Arctic America.

R. D. GEORGE.

The Freshwater Tertiary Formations of the Rocky Mountain Region. By W. M. DAVIS. Proceedings of the American Academy of Arts and Sciences, Vol. XXXV, No. 17, March, 1900.

In this very timely paper Professor Davis gives voice to a growing change of opinion regarding the specific mode of origin of the most

characteristic class of formations of the Rocky Mountain Tertiaries. During recent years not a few geologists, here and there, have expressed a disposition to regard some of the deposits usually assigned to lakes as the products of stream action or "sheet wash," or of a combination of these with lake deposition. To the reviewer, who is among these dissenters, the favorite illustration of such modes of deposition is the present and recent accumulation in the Great Valley of California where several forms of subaërial aggradation are conjoined with lacustrine and marine deposition. This newer mode of interpretation has been applied to a notable series of formations distributed at intervals from the Medina, and even the Keweenawan, to the Lafayette and the recent deposits of the great basins of all the continents, particularly the arid basins. The great red terranes, with their associated products of desiccation and saline concentration, especially, have seemed to the reviewer attributable to such combined action, since a basin of saline concentration carries in its very terms the idea of a basin of detrital lodgment whose central part may be an area of subaqueous deposition but whose border is almost inevitably a zone of subaërial accumulation. The doctrine of non-lacustrine basin-aggradation, as it lies in the mind of the reviewer, has its most distinctive application to tracts of relative aridity, for it is in these, chiefly, that the conditions of subaërial lodgment preponderate over the conditions of subaqueous deposition, except in the case of aggrading river bottoms near base level which are undergoing a depression of gradient by deformation. In an arid basin-tract the precipitation is likely to be greatest on the elevated rim, and there it is often spasmodic, taking the form of cloudbursts and similar intensified forms. The gradient is also highest, as a rule, in the rim zone. These form a combination of agencies which result in an exceptional transportation of detritus down the slopes of the basin rim followed by a marked reduction of power of transportation as the flatter part of the basin is reached; for there the flood loses its power by lowered gradient, by spreading, by absorption, and by evaporation. Deposition is the usual consequence. In a humid region, the conditions are largely reversed; the streams augment in volume as they flow over the basin-plain and the power of transportation is more or less fully maintained. If the basin be a closed one the accumulated waters arising from the excess of precipitation over evaporation soon cover the basin floor with a lake which occupies the territory that in an arid region would be

covered in large part with subaërial detritus. In a humid region with free drainage no great thickness of detritus can usually be built up on the floor of a basin without increasing the gradient so as to suspend the process of aggradation, unless movements of deformation or changes of sea-relationship intervene to renew and perpetuate the conditions of aggradation. This of course may happen, but it is rather to be classed as an accidental intervention than as a systematic process.

The presumptions therefore seem to lie on the side of lacustrine deposition, with incidental fluvial aggradation, in humid regions, while in arid regions they lie on the side of fluvial aggradation, with incidental lacustrine deposition. To the reviewer, therefore, the question has a specific climatic relationship and this relationship seems much the most important phase of the subject. Given the same humidity, and the ratio of lacustrine to fluvial deposition is dependent on surface adjustments of a local nature. Given the same surface adjustments, and the ratio of lacustrine to fluvial deposition is dependent on states of humidity or aridity. But the humidity or the aridity of an area large enough to have geological importance, implies atmospheric states that are a function of the whole atmosphere, and of its modes of circulation, and hence has far-reaching significance.

If these considerations have any validity, the question which Professor Davis pointedly raises regarding the Rocky Mountain Tertiaries, as a specific example of the class under question, deserves the most critical attention. The value of an academic discussion, which is often unwisely underrated by the working field geologist, lies chiefly in deploying the problem and laying the groundwork for discriminative observations. Professor Davis seems to be altogether correct in pointing out a lack of critical observation and interpretation in most previous studies of the Tertiaries in question, and his discussion can hardly fail to call forth incisive studies upon these formations. Obviously their true character can only be determined by such critical field studies. A first step is the establishment of criteria of discrimination between lacustrine and fluvial deposits; by no means an easy task where the products of relatively shallow lakes are to be distinguished from those of rivers, which is really the critical case. It is not clear that the criteria given in the paper will always hold good, but there are several additional ones that may be brought into service, such as the distribution of the remains of land animals in the midst of

the basin, the occurrence of marsh-formed or land-formed lignites in similar situations, the interstratification of beds of gypsum or other desiccation products, and analogous criteria that imply aërial conditions. T. C. C.

The Crystal Falls Iron-Bearing District of Michigan. By J. Morgan Clements and Henry Lloyd Smyth, with a chapter on the Sturgeon River Tongue by William Shirley Bayley and an Introduction by Charles Richard Van Hise. U. S. Geological Survey. Monograph XXXVI. Washington, 1899.

This report is the third in a series of four monographs on the iron-bearing district of the Lake Superior Region. Two having been published previously: one on the Penokee district (Monograph XIX). The other on the Marquette district (Monograph XXVIII). The fourth, on the Menominee district, is to follow.

The Crystal Falls district was divided areally, the western half being studied by Mr. Clements and the eastern half by Mr. Smyth, and the Sturgeon River Tongue by Mr. Bayley. The investigation was conducted under the charge of Mr. Van Hise, who sums up the general results in an introductory chapter. The district embraces 840 square miles. As pointed out in the introduction the rocks belong to the Archean and Algonkian. The latter consisting of a Lower Huronian and an Upper Huronian separated by unconformity. The Archean is believed to be wholly igneous in origin, it occupies a broad area in the eastern part of the district and has not been closely investigated. Several smaller areas occur within parts of the region carefully studied. Owing to the readily decomposable nature of the rocks in places and to the drift mantle the detail character of the formations is unknown for part of the area described by Clements, and in the belt worked by Smyth the rock surface is almost wholly concealed by glacial deposits and vegetation. It will be seen under what adverse circumstances the field work was carried forward, and how much credit is due the geologists who have brought to light so much valuable information from so unpromising a region.

The Lower Huronian consists of quartzite, dolomite, slate, a volcanic formation, and some schists. The series has a minimum thickness of 2200, and a possible maximum thickness of 16000 feet. The sediments probably nowhere exceed 5000 feet in thickness. The Upper Huronian

is a great slate and schist series, not separable into individual formations, and whose thickness cannot be approximately estimated. All of these formations have been cut by igneous rocks of various kinds and at different epochs.

Metamorphism has greatly altered the character of the Algonkian rocks. In the Lower Huronian the quartzite is the altered form of a sandstone and conglomerate in which the pebbles have been nearly destroyed. It is in places schistose. The dolomite is a nonclastic sediment. The slate or schist is an altered mudstone. The volcanic formation is perhaps the most characteristic feature of the Crystal Falls district. It occupies a larger area than the other Lower Huronian formations and consists of basic and acid rocks, lavas and tuffs, with subordinate interbedded sedimentary rocks. The iron-bearing formation, called the Groveland, consists of sideritic rocks, cherts, jaspillites, iron ores, and other varieties characteristic of the iron-bearing formations of the Lake Superior region.

After elevation and unequal erosion of the Lower Huronian, conditions of deposition covered these formations with sandstone and slate conglomerate, passing upwards into shales and grits, subsequently altered to mica-slates and mica-schists. These were followed by combined clastic and non-clastic sediments, the latter including iron-bearing carbonates. Above these is a great thickness of mica-slates and mica-schists.

After a long period of deposition a profound physical revolution occurred, raising the region and folding it in a most complex manner. The folds have steep pitches indicating great compressive stresses in all directions tangential to the surface of the earth. Subsequent to or during the late stage of this time of folding there was a period of great igneous activity, probably contemporaneous with the Keweenawan, intruding within the rocks vast bosses and numerous dikes of peridotites, gabbros, dolerites and granites. These intrusives, while altered by metasomatic changes, do not show marked evidence of dynamic metamorphism.

Subsequently the region was subjected to great denudation and reduced approximately to its present configuration. In late Cambrian time Upper Cambrian sediments were deposited upon it. Whatever may have been deposited upon the Cambrian has been removed by erosion together with most of the Cambrian. If the region was again submerged in Cretaceous times no evidence of the fact remains.

During the Pleistocene period a thick mantle of glacial deposits was spread over the entire area, which has been eroded far enough to uncover the rocks here and there.

Clements's description of the western part of the district treats of the surface features, the economic resources and the petrographical character of the various formations, especial attention being paid to the volcanic rocks. The great abundance of volcanic breccias and tuffs indicates the probable existence in Huronian time of a volcanic cone in this region, but the possible location of its vent has not been discovered. A small part of the igneous rocks are acid, their area being too small to map on the scale of publication. They include rhyolite-porphyries and aporhyolite-porphyries and breccia of the latter. The great part of the volcanics are metabasalts and breccias of the same. An interesting development of ellipsoidal structure is noted. The pre-Cambrian intrusive rocks include granites and rhyolite-poryhyry, metadolerite, meta-basalt and picrite-porphyry, besides a series considered to be closely connected genetically ranging from granite, tonalite and quartz-mica-diorite through diorite, gabbro, and norite to peridotite. The diorite is closely related to monzonite.

In the second part of the monograph Smyth discusses at length the effect of buried magnetic ores on the magnetic dip needle, describes its use and the results of careful observations in locating the iron-bearing deposits. He also describes the different formations structurally and petrographically. The same is done by Bayley for the Sturgeon River Tongue.

J. P. I.

The Geography of Chicago and its Environs. By ROLLIN D. SALISBURY and WILLIAM C. ALDEN. Bulletin No. 1 of the Geographic Society of Chicago, published by the Society. Chicago, 1899. 64 pp.

This pamphlet is a model essay on local geography written in an interesting style and illustrated in an attractive and instructive manner. From the maps and descriptions it is learned that Chicago is situated on a plain which stretches from Winnetka, sixteen miles north, to Dyer, about twenty-eight miles south of Chicago, and sweeps eastward around the southern end of Lake Michigan. This plain is narrower at its extremities and has a maximum width of fifteen miles in about the latitude of Chicago; it is limited on the east and northeast by Lake

Michigan, on the west and southwest generally by the Valparaiso moraine which loops around the southern end of Lake Michigan, through northern Indiana into Michigan. The plain topography is varied by three prominent "islands:" Stony Island, a drift-covered, dome-shaped hill of Niagara limestone with quaquaversal dip; Blue Island, a single morainic ridge about six miles long and fifty feet above its surroundings; and Mt. Forest Island, a portion of the Valparaiso moraine about 120 feet higher than the plain, separated from the rest of this moraine by the Chicago outlet. The plain is continued through the Valparaiso moraine southwest of Chicago by the Chicago outlet, which is divided by Mt. Forest Island into the Sag outlet and the Des Plaines outlet. The Des Plaines outlet is now followed by the Chicago Drainage Canal. Several less conspicuous gravel and sand beach ridges converging toward the Chicago outlet from the northeast and southeast help to break the monotony of the plain. On these ridges are oak groves, which have apparently suggested the names for the towns Oak Park, Oak Lawn, Englewood and others. The eastern third of the plain is largely made of gravel and sand. With the exception of the beach ridges, the western two thirds is largely of till. These deposits vary in depth from 0 to 130 feet. The country rock is Niagara limestone which has an elevation varying from 124 feet below the lake level to about 20 feet above it in Stony Island, and 100 to 110 feet above it under the Valparaiso moraine. The southeastern edge of the plain is occupied by a series of small lakes, the basins of which are in large part made by enclosing beach ridges. At the south end of Lake Michigan there are sand dunes with a maximum height of 100 to 200 feet. Other smaller dune areas exist nearer the city.

The main recorded events in the geographical history of the region since Devonian times are: (1) Withdrawal of the sea and destruction of formations younger than the Niagara with the exception of some fossiliferous Devonian material preserved in joints of the Niagara formation; (2) invasion of the ice in the glacial period, rounding off the angularities of the rock surface and probably diminishing the relief of the region by deposits of drift. At a late stage of the ice invasion the Valparaiso moraine was made. (3) As the ice edge retreated from the Valparaiso moraine a lake accumulated in the depression between the ice front and the moraine until the water stood at an elevation sixty feet above the present Lake Michigan when it overflowed to the west through the valley of the Des Plaines River and through the Sag outlet. To

this lake Mr. Leverett has given the name Lake Chicago. The stages in the history of this lake are as follows:

(*a*) Glenwood stage, the highest stage, when the level was sixty feet higher than Lake Michigan is now. During this stage the outlet was cut down twenty feet.

(*b*) A stage of recession, when discharge through the Chicago outlet ceased and the water withdrew from the Chicago plain in part or entirely. During this stage deposits of peat accumulated.

(*c*) Calumet stage, in which the water again discharged through the Chicago outlet at a level forty feet higher than the present level of Lake Michigan. During this stage the Calumet beach was formed over the peat deposits of the preceding stage.

(*d*) The lowering of the outlet gradually reduced the level of the lake twenty feet when the Tolleston beach was formed.

(*e*) A lower outlet was opened to the north and the lake fell below the level of the Chicago outlet. This closed the history of Lake Chicago and inaugurated that of Lake Michigan. Between the Tolleston beach and the shore of Lake Michigan there is an extensive series of sand and gravel ridges among which lie the small lakes mentioned above.

Abundant evidence of fresh water life has been found in the deposits of the Tolleston stage of the lake, but not in the deposits of earlier stages. On the surface of the Calumet beach, however, marine shells of southern species have been found, which may have been introduced artificially.

The bulletin is essentially a popularized version of the work of the United States Geological Survey and is a tribute to the value of its investigations. It is to be hoped that this bulletin will stimulate the publication of similar essays on local geography elsewhere. Interest in geography is certainly increased by such publications.

CHARLES EMERSON PEET.

Recent Publications

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Nineteenth Annual Report, 1897–8, Part II. Papers chiefly of a Theoretic Nature. Part III, Economic Geology. Part V, Forest Reserves, Atlas accompanying.

Twentieth Annual Report, 1898–9, Part I, Director's Report, Triangulation and Spirit Leveling. Part VI, Mineral Resources of the United States, 1898. Metallic Products and Coke. Part VI continued, Mineral Resources of the United States, 1898, Non-Metallic Products except Coal and Coke.

Monograph XXXII, Part II, Geology of the Yellowstone National Park. Descriptive Geology, Petrography, and Paleontology, Hague, Iddings, Walcott, Stanton, Weed, Girty, Knowlton.

Monograph XXXIII, Geology of the Narragansett Basin. Shaler, Woodworth, Foerste.

Monograph XXXIV, Glacial Gravels of Maine and other Associated Pleistocene Deposits. Stone.

Monograph XXXVI, The Crystal Falls Iron-Bearing District of Michigan, with chapter on the Sturgeon River Tongue. Clements, Smyth, Bayley, Van Hise.

Monograph XXXVII, Fossil Flora of the Lower Coal Measures of Missouri. White.

Monograph XXXVIII, The Illinois Glacial Lobe. Leverett.

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